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ABSTRACT

The major idea of the unit is: a scientist thinks in terms of relationships rather than absolutes. Twenty-nine inquiry oriented laboratory experiences are arranged under the headings: (1) measurements express relationships, (2) patterns govern relationships, (3) frames of reference determine relationships, (4) heredity and environment are necessarily related, (5) rates and changes are necessarily related, and (6) man and his tools are necessarily related. The laboratory experience format throughout is as follows: Introduction, Materials and Equipment, Collecting Data, and Follow-up. Experiences cut across many subject matter areas and include topics such as "development of the chick embryo" and "calories and degrees," but all are designed to develop an understanding of the main idea of the unit. (BR)

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IDEA-CENTERED LABORATORY SCIENCE

(I-CLS)

The Kind of World a Scientist Thinks He Has Found

Unit E. A Scientist Thinks in Terms of Relationships Rather Than Absolutes

A scientist is unable to find sharp boundary lines in the natural world. He finds instead that the world consists of intergrading sets of relationships. He thinks of the world not as "blacks" and "whites," but as varying shades of "gray." Even these do not stay the same. They change and shift and blend, depending on where they are and when they are in relation to one another.

A scientist dislikes absolutes, things that are as they are, always have been and always will be, and therefore are not open to question or investigation. He believes that the world consists of sets of relationships rather than absolutes.

This Idea of Relatedness underlies all of a scientist's thinking and actions and the way that he looks at his world.

SE 008 856

The Kind of World a Scientist Thinks He Has Found

Unit E. A Scientist Thinks in Terms of Relationships Rather Than Absolutes

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E.1. Idea That Measurements Express Relationships

Idea Bridge: Quantifying Our Relationships With Our Environment

Measurement is meaningless unless it expresses a relationship. We measure weight in relation to the pull of gravity. If we are using a balance type scale, and one side of the balance sinks lower than the other, we express the difference in terms of units of weight. If we are using a spring type scale we measure the downward pull in terms of the extent to which the spring is depressed.

We have seen (B.2.f.) how we measure time in relation of cycles. These may be natural cycles, like the cycle of day and night, and the lunar cycle, or the cycle of the seasons. Or they may be artificially created cycles like the behavior of a clock, or the passage of an arbitrary period of time, like a week or a century.

We measure many things in relation to the average of their group, calling this the norm. We have seen how we do this with normal weight (D.1.c.). We do it also with the norms of standardized tests in school.

We have seen also how we measure all kinds of things in relation to artificially created units of measurement (inches, millimeters, pounds, kilograms, quarts, liters, and many others (B.2. Idea of Quantification). In connection with this Idea we have also seen how the significance of particular measurements changes in relation to the things being measured, and the use that is made of the measurements.

We are now ready to explore further the Idea of Measurement as an Expression of Relationships through laboratory experiences which deal with various specific relationships.

LABORATORY EXPERIENCE E.1.a.

A Simple Balance

Introduction:

Try to think what it would be like to be in a place where you didn't have any way to measure anything. How would you say how long a piece of wood is, how deep a body of water is, how cold the day is, or how heavy something is? You might say, "that piece of wood is as long as my arm," or "the water in that pool is over my head." "It is colder today than it was yesterday." You might say, this bag of groceries is as heavy as that rock," or "It is as heavy as two rocks." You probably wouldn't say things this way but you could because you would be showing relationships. Comparing is a way of showing relationships.

We express measurements by comparing the thing we want to measure with something else. Long ago people began to use standard units of measurement (pounds, ounces, feet, inches, or kilograms, grams, meters and centimeters) to say how heavy something is or how long it is. These units of measurement mean the same to everybody who uses them. They are a convenient way of quantifying (telling in terms of quantity) what we think about things in our environment.

Actually, the standard units of measurement that we use are not a part of nature. A "foot" was the length of the foot of an English king. A "yard" was the length of the arm of another king. The height of horses was measured in units called "hands." An old English unit of weight was a "stone." The "meter" was set as one ten-millionth of the distance from the equator to the north pole of the earth. All of these units were decided on and used because all of the people who used them agreed as to what they meant.

You can set up a system of measurement of your own for use in a laboratory experience. When you do this it will help you to think of measurements as a set of relationships.

Materials and Equipment:

Yardstick (new, clean, and as free of knots as possible)

Triangular file

Frozen fruit juice cans, with tops removed

Soft wire

BB shot

Forceps for handling BB's

Pennies (new ones, if possible)

String

Ruler

Support for suspension of balance (ring stand or other)

Collecting Data:

Carefully make a notch with the triangular file across one edge of the yardstick at its exact midpoint. This notch should be deep enough to hold the string. Now cut a piece of string about six inches long, and tie it around the stick with the knot lying in the notch. Leave the two ends of the string of equal length. Tie these ends together and hang the stick from the support. Do the two ends of the stick balance, or is one end higher than the other. Why?

Now carefully make shallow notches across the upper edge of the stick at each quarter-inch mark. Start at the midpoint where the string is tied, and make notches from there to each end. Be careful to make each notch straight across the top of the stick, and make all of the notches as nearly the same depth as possible. Be sure to make each notch exactly on the quarter-inch mark. Hang the stick on the support again. Is it as well balanced as it was before. If it isn't, what do you think may have happened? Why?

Punch a small hole on each side of two fruit juice cans from which the tops have been removed. Cut two pieces of wire of equal length. Pass a piece of wire through the holes in each can. Tie the ends in such a way that the can may be hung from the stick, and may be moved along the stick from one notch to another.

Hang the empty cans from the last notch at each end of the stick. Do the ends balance? Change ends with the cans. Do they hang the same regardless of the end on which they are hung?

Either the stick or the cans or both may not be completely balanced. Choose one can for the right side and one for the left side and mark them. Use them this way from this point on. Add BB's to the can that hangs the highest to bring that side into balance. Write down the number of BB's used, and leave them in the can from this point on. They make up the necessary correction factor at this point.

Now add 50 BB's to each can. Are the sides still in balance? Does the correction factor still hold true? If not, can you suggest a reason why? Test your hypothesis, if you can think of a way of doing so. In any case, adjust your correction factor, if necessary, by adding or subtracting BB's on one side or the other, and proceed. Be sure to keep a record of what you have done. Why?

Move both of the cans containing the BB's toward the center, one quarter-inch on each side at a time. Bring them as close together as you are able to without the cans touching. Keep the two sides in balance. Add or subtract BB's as necessary to do this. Keep a record of the number of BB's used, and the points where corrections are made. If adjustments are necessary, can you suggest a reason why? Test your hypothesis if you can think of a way of doing so.

Now remove all BB's from both cans, and hang the cans at a point three inches (12 quarter-inches) on each side of the midpoint. Bring them to a balance. Add BB's to serve as a correction factor if necessary.

Put a penny in the left hand can. Add BB's to the right hand can to balance the penny. How many BB's are necessary? Add a second penny to the left hand side, and move the right hand can out from the center one quarter-inch. Add BB's as necessary to get a balance. Record the data. Keep on adding pennies to the left hand can, one at a time. For each penny added, move the right hand can out from the center another quarter-inch, and add BB's as necessary to get a balance. Always record the data.

You are now weighing the pennies, using "quarter-inches" and "fractions of of quarter-inches" as weight units. The fractions of quarter-inches are expressed in terms of BB's. In this way a penny may weigh "one quarter-inch and two BB's, in the same way that a thing might weigh "one pound and two ounces."

Does each additional penny that you add weigh the same, as you move the can from near the center toward the right end of the stick? If there are any differences, are they consistent? That is, do they change in the same direction and at the same rate as you move along? Is there a trend? Figure out the average. Try to state a reason for what you find. Test your hypothesis if you can think of a way to do so. Try beginning farther from the center. Try changing sides. Do the ages and relative amounts of wear of the pennies make any difference? Try to think of other possible explanations that you can test.

Now find out the value of a quarter-inch in terms of BB's. Start with empty cans at the twelfth notch (three inches) from the center on each side. Balance the can again, using whatever correction factor is necessary. Then put 50 more BB's in each can to start. Move the right hand can outward one quarter-inch at a time, and add BB's to the left hand can each time as necessary to maintain a balance. Record the number of BB's added to balance each additional quarter-inch that the right hand can is moved. Is the number the same each time? Is there a trend? Figure out the average. Are your results consistent with the results you got with the pennies? Suggest a possible explanation of what you have found. Test your hypotheses if you can figure out a way to do so.

It would be a good idea at this point to re-do the whole experience, using new materials throughout, to see if your results are the same, or are understandably related to the results you got the first time.

Follow-Up:

Both equal arm and unequal arm balances are used to weigh quantities. They are actually more accurate than "spring type" scales. Which was yours, an equal arm or an unequal arm balance? Why? Ordinary laboratory balances are equal arm balances. Unequal arm balances were formerly in use on farms and elsewhere to weigh sacks of grain and other quantities. They were made from strips of steel with notches on one edge, and were called "steelyards." The use of balances of this kind goes back to pioneer times in America, and to the Middle Ages in Europe.

You can figure out the approximate margin of error on your balance. First, weigh a ten gram weight on your balance, and find out the value of this weight in terms of quarter-inches and BB's. Figure out the value of a single gram from this. Then weigh various objects on your balance in quarter-inches and BB's. Translate these weights into grams. Then weigh the same objects again on a laboratory scale and compare these weights with the ones you got on your balance. How accurate was your balance?

LABORATORY EXPERIENCE E.1.b.

Depth and Pressure

Introduction:

Air pressure at sea level is much greater than air pressure on a mountain peak. Many factors influence this, but one of the important ones is the difference in depth (height) of the air column pressing down. A barometer is used to measure the relationship between air pressure and the column of mercury supported by this pressure.

The relationship of depth to pressure on a object submerged in a liquid can also be expressed in terms of measurement.

Materials and Equipment:

A glass funnel with diameter small enough to pass through the opening of a quart milk bottle or carton.

Plastic or rubber tubing (to fit standard glass laboratory tubing snugly)

Rubber balloons

Glass tubing

Waterproof tape (the kind that can be used to repair garden hose)

Pegboard, masonite or scrap lumber to use for supports

Tall, leak-proof waste basket

Quart milk bottle

Bunsen burner or other heat source for bending glass tubing

Materials for making measuring scales

Rubbing alcohol

Table salt

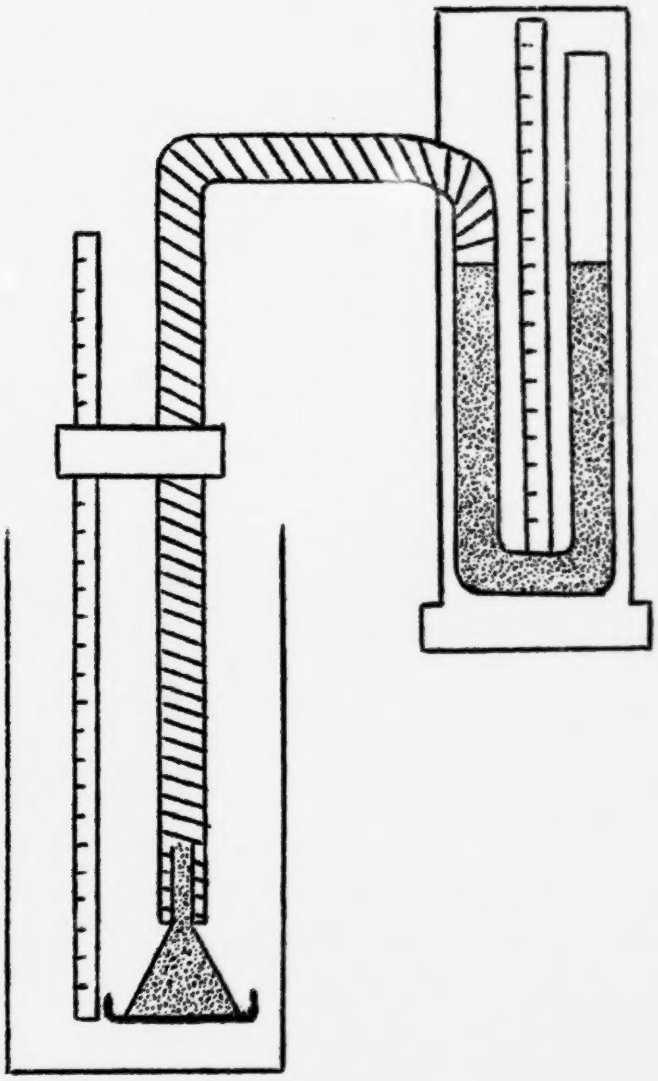
Food coloring

Graph paper

Procedure:

This experience will require two or more laboratory periods. Work in groups of convenient size.

Although the accompanying diagram is provided as a general guide, the preparation and assembling of the equipment is your problem. There are alternative ways in which it might be done, possibly even better ways. If you wish to try another way, feel free to do so.



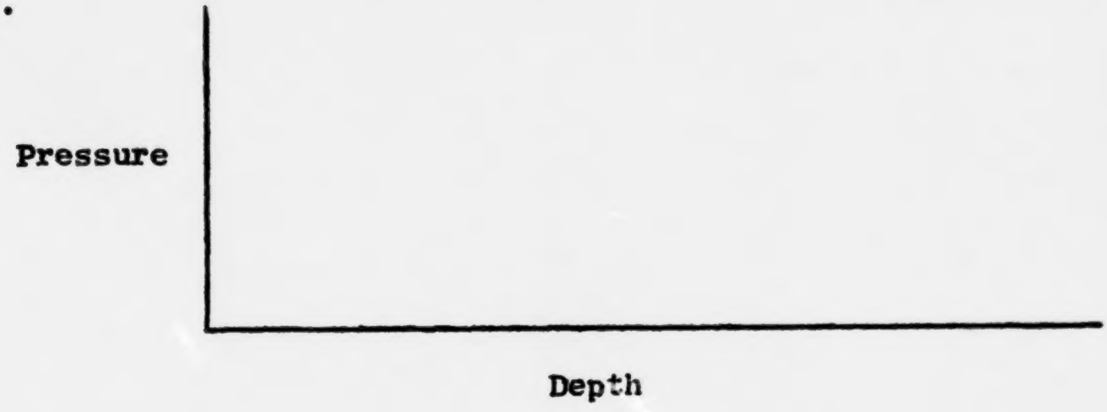
In any case, the glass tubing must be heated, bent to form a U-tube with one arm longer than the other, and mounted on a support. Ask your teacher to show you how to bend glass. The funnel may also be supported, but must remain movable. The thin, rubber membrane from the balloon must be fastened tightly across the opening of the funnel. The rubber or plastic tubing must be affixed to the glass tubing so that it is air tight.

A means of measurement must be used. Use standard units, such as inches or centimeters, or devise a scale.

Pour water containing food coloring into the U-tube until it stands about 3 inches high in each arm.

Lower the funnel mouth in stages into the water in the wastebasket. As it goes deeper beneath the surface there should be a noticeable change in the position of the liquid in the U-tube. What happens? Is there a relationship between depth of the funnel mouth and level of the colored water in the U-tube? Why?

Repeat the experience and make careful measurements. Record these data for at least 10 depths. Is there evidence that there is an increase in pressure with increasing depth? Is this relationship constant? Graph your data.



Use the milk bottle or carton in place of the wastebasket, and repeat the experience, make the measurements, and construct another graph.

When you have carried out this experience with both the wastebasket and the milk bottle, see if there is a relationship between the two sets of data. What conclusion can you draw?

Repeat the experience with the milk bottle, but use a saturated solution of table salt instead of water. Compare your results with those obtained with water. What is the relationship? What conclusion can you draw?

Repeat the experience with the milk bottle, but use rubbing alcohol instead of water. Compare your results with those obtained with water. With the salt solution. What are the relationships? What conclusion can you draw?

Follow-Up:

How are we justified in saying that measurements are only a quantitative statement of relationships?

What animals are equipped by nature for dealing with the environment beneath the surface of the water? What happens to a large whale when it runs adrift on a shore? What happens to a deep sea fish when it is brought to the surface? Why?

What happens when a skin diver goes beneath the surface of a pool, lake, river, or the ocean? This is not a natural environment for a human. What equipment does he use for dealing with it? What are the hazards? Why do they exist?

What happens to a deep sea diver when he comes to the surface too quickly? Why? What about a submarine? With what devices is it equipped for dealing with the environment? How are these devices which man has evolved to meet an environmental challenge comparable to the results evolved by nature in the case of water-dwelling animals to meet the same challenge?

LABORATORY EXPERIENCE E.1.c.

Calories and Degrees

Introduction:

Two common units for the measurement of heat are calories and degrees. This laboratory experience will show you how these units of measurement are related to one another, and what variables determine this relationship.

Materials and Equipment:

Two bunsen burners

Two identical florence flasks

Water

Two ring stands

Two thermometers

100 cc graduate cylinder

Watch with second hand

Graph paper

Collecting Data:

Put 100 cc of water into a florence flask. Put 200 cc of water into a second florence flask. Place a thermometer in each flask.

Light two bunsen burners, and adjust them so the flames are as nearly alike as possible. Put the two flasks on two ring stands over the flames. Read and record the temperatures every 30 seconds for five minutes.

Since you have adjusted the bunsen burners to be as nearly alike as possible, would you say that the two flasks are receiving approximately the same amount of heat? Amount of heat is expressed in terms of calories. We will not try to measure the number of calories, but we are observing the effect of approximately the same number of calories on the two different volumes of water contained in the flasks.

What is the effect? Is it the same in the case of both flasks? Plot the rising temperature in each flask on the same sheet of graph paper. Compare the two graphs. Does the temperature (measured in degrees) rise at the same rate in both? Why or why not? If you have a hypothesis to explain your observation, can you think of a way to test it?

How is temperature related to calories? To volume? What other factors might affect the temperature? Do all kinds of materials heat up at the same rate? What is meant by specific heat?

Follow-Up:

Why is the water in a small inland lake warmer (degrees) on a summer day than the water in a large lake, when they are both receiving the same amount of heat per unit of area from the sun (calories)?

Think of other examples of differential heating when two objects are receiving the same amount of heat (calories).

LABORATORY EXPERIENCE E.1.d.

Speed---A Relationship

Introduction:

"I drove the five miles from home to school in ten minutes. How fast was I driving?" This is a common type of mathematical problem. "Speed limit: 70 miles per hour." This is a common sign along expressways and toll roads. There is a relationship between distance and time. It is expressed in terms of speed. What is speed?

Materials and Equipment:

Graph paper

Meter stick

Yard stick

Stop watch (a watch with second hand may be used but works less well)

Collecting Data:

Use a long corridor, a stretch of sidewalk, or a line on the schoolground to travel a measured distance. Measure the distance in meters.

Find, to the nearest second, how long it takes several different students to

a. walk slowly
b. walk rapidly
c. run

this distance.

Find by calculating how many meters each one goes in one second (a) walking slowly, (b) walking rapidly, (c) running. Find the average distance traveled in meters per second by persons in the group (a) walking slowly, (b) walking rapidly (c) running. How can you find these averages?

From the following data, construct a graph of the speed of a vehicle traveling along a highway.

Time in minutes	Distance in miles
0	0
5	3
10	6
15	9
20	12
25	15
30	18

Did the speed of the car change during the trip?

How far had the car traveled at the end of 18 minutes?

If the speed remains constant, how far would the car travel in one hour?

What was the speed of the car in miles per hour?

Note that a speed of "x" miles per hour implies neither an hour's travel time nor a distance of "x" miles. Only if the rate were constant and an hour's travel time were consumed, would "x" miles have been covered; or if "x" miles had been covered one could presume to have been traveling for one hour's time.

Follow-Up:

Since a second is the unit of time used in both the English system of measurement and the metric system, use the same distance that you did before, but this time measure it in feet. Find the speed of the students in feet per second, feet per minute, feet per hour, and miles per hour.

If you were driving a foreign car whose speedmeter read "kilometers per hour" instead of "miles per hour," how would you change one to the other in your thinking?

A scientist speaks of velocity and acceleration. How are these related to speed? Why might a penny dropped from the top of the Empire State Building penetrate the skull of a person it strikes? What is meant by negative acceleration?

E.2. Idea That Patterns Govern Relationships

Idea Bridge: We Use Patterns Up All The Time and So Does Nature

Almost everything we do depends on some kind of a pattern. We wish to build a new building or remodel an old one. We must first get an architect to prepare a set of plans. These plans are really patterns. In preparing the plans, the architect must follow the recommendations of the city building authority. This authority must ultimately give approval to what he has done. Finally the contractor who works on the building must follow the plans (patterns) that the architect has made.

A woman makes a dress. She follows a pattern. The decoration committee for a school party cuts out stars and other figures from colored paper to hang from the ceiling. They use patterns in doing this. The assembly lines in an automobile factory are set up for the production of a new model car. The engineers have prepared plans (patterns) which are followed in every detail.

The federal government sets guidelines (patterns) for the settlement of industrial disputes. The state educational authority adopts standards (patterns) for the preparation of teachers. Courts hand down decisions in cases of law which then serve as precedents (patterns) for dealing with future cases of the same kind. We follow customs (patterns) of long standing which are part of our culture. These determine our behavior with regard to courtship and marriage, death and burial, and other major events of life.

In our daily activities we depend on conditioned responses (established patterns of behavior). We eat with certain table instruments and utensils, used in a particular way. We dress each day in certain clothes which our society accepts as appropriate for our sex, age, and particular activities. All of these depend on conditioned responses (patterns). Our daily problems are pre-solved for us in large part by these patterns. If it were not for them, each of our actions would have to depend on a new and independent decision. Our days would be taken up with these trifling decisions, and we would have little time left for facing new problems involving decisions for which we have no patterns to follow.

Relationships in the natural world are similarly dependent on patterns. In an earlier unit (A.5. Idea of Natural Law) we saw that natural laws are actually descriptions of consistently operating patterns in nature. Therefore our use of patterns in the man-made world follows a natural precedent or pattern which was in existence long before we appeared on the earth. Since man is a part of nature, it would have been impossible for us to operate in any other way.

We are concerned in this unit with the ways in which patterns are passed on or transferred. We will be able to examine only a few cases and methods of transfer. Some of these are quite simple. Others are very complex. First we will look at some of the simplest ones. Then we will study some of the more complex ones. You should follow the increasing complexity as far as you can. In doing this you should always keep in mind the Idea of Transference of Pattern. By this we mean transferring a pattern to make new examples like itself; transferring a pattern from one means of carrying it to another; transferring a pattern from one generation to another. Transference of pattern is a widely applicable principle.

LABORATORY EXPERIENCE E.2.a.

Replicating Simple Patterns

Introduction:

We follow simple patterns in almost everything we do. Nature does the same thing. The leaves of one kind of tree all follow the same pattern. All animals that belong to the same species look very much alike. Think of other examples.

When we use something as a pattern to make another thing like itself, we say that we replicate it. There is almost no limit to how many times we can replicate a pattern. When we use a pattern in this way we say that it serves as a template.

A key serves as a template when we have a duplicate key made. How is this done? A dress pattern serves a template for cutting and assembling the material for a dress. It would be possible to make any number of keys or dresses that are all alike, by using the same templates. How are these keys and dresses related to the patterns and how do they interrelated to one another. The principle of interchangeable parts, which is one of the foundations of mass production in modern industry, is based on the use of templates or patterns.

In this laboratory experience you will have an opportunity to examine various simple cases of replication, and as you do so, to consider the Idea that various kinds of templates or patterns govern relationships between things that are alike.

Materials and Equipment:

Sheets of 8½" x 11" typing paper

Scissors

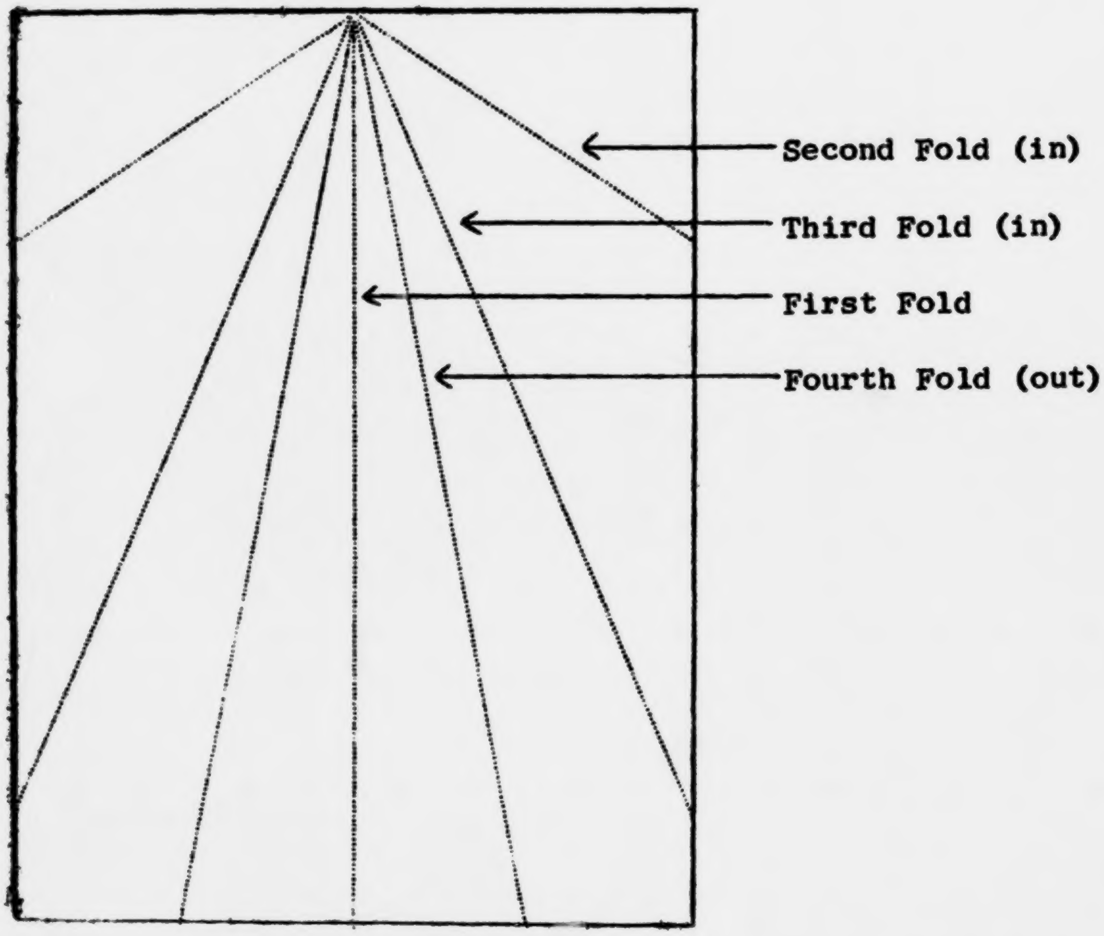
Ruler

Collecting Data:

Fold a sheet of 8½" x 11" typing paper in half three times. Make each of the folds as neat and even as you can. This will give you a rectangle of folded paper that is 8-ply in thickness, measuring 4½" x 2 3/4" on the sides. Now, cut out triangles or rectangles of various sizes from the edges of each of the four sides. Always cut along straight lines. Unfold the paper and see what kind of design you have made.

Replicate this design with another sheet of typing paper. How many ways can you think of to do this? Try at least two different ways. Is one method better than another? Why? Is one method faster than another? Why? If you had to replicate the design ten times, what method would you use?

Make a paper dart, as follows: Fold an 8½" x 11" sheet of typing paper exactly in half, lengthwise (the first fold). Fold one end of each half in, exactly to the center line (the second fold). Fold the same end of each half in again, exactly to the center line (the third fold). Now fold the same end of each half out, again exactly to the center line (the fourth fold).



See how far you can sail the dart. Keep a record. You may work with other students and make a contest of it, if you wish. Sail the dart at least ten times. What is the greatest distance you can sail it? What is the average distance?

Do you think you can improve the dart by modifying the design? Try any modifications that you think might serve as improvements. Keep records of all trials. Replicate your most successful design. Test each copy of it several times to see if the results are consistent. Suggest an explanation for the success of your best design. Test your hypothesis if you can think of a way to do so.

Ask another student to write his name on a clean sheet of typing paper three times. Space the signatures about two inches apart from one another. Then ask him which one of the three signatures he would like you to replicate. Cut three strips from the paper with a scissors, each containing a signature. You now have each signature on a separate strip of paper.

Now take a second sheet of paper and fasten the signature that is to be replicated at the bottom of it, using paper clips to hold it in place. Turn the sheet of paper upside down so that the signature is now at the top of the sheet, upside down. Just beneath the strip containing the signature, draw the signature, slowly and carefully, beginning at the back end. You will be drawing the signature rather than writing it, copying it backward and upside down. When you replicate it in this way you cannot write it. You have to draw it. Be as careful as you can.

Now compare your replication with the original signature that you copied. How alike is it? Then compare the replication to each of the other two original signatures. Of the four signatures, which two are most alike?

Follow-Up:

Take an automobile switch key, or other key of the same type, to a place where keys are replicated. Watch the new key being made. How is it done? What is a "key blank"? Are all key blanks the same? Are there different kinds? How do they differ from one another? Can all types of keys be replicated in the same way? Why or why not? Think of other examples of replication from a template which result in a series of related objects.

LABORATORY EXPERIENCE E.2.b.

Patterns in Communication

Introduction:

People communicate by means of hearing and sight. These senses are able to detect patterns of light and sound. These patterns are made up of light waves and sound waves. The patterns are formed by variations in length and strength of the waves. Wave length is the distance from one wave to the next. Wave strength is the amount of energy that is in the wave.

One kind of waves that everyone knows about is waves on the water. Their wave length can easily be seen by watching them. Their wave strength is expressed by their height. When a high wind is blowing on the surface of a lake, the waves are high. Much of the energy of the wind is going into the waves.

The wave length of sound waves is expressed in pitch. A high note in music has shorter wave length than a low note. The wave strength of sound waves is expressed in loudness. A loud sound has more energy in it than a low sound. The wave length of light waves is expressed in color. Each color consists of light of a different wave length. The wave strength of light waves is expressed in brightness. The brighter the light, the more energy there is in it.

Patterns of wave length and wave strength of sound waves and light waves in relation to our ears and eyes make it possible for us to communicate.

Materials and Equipment:

A sink or basin full of water

A tuning fork

A prism

A piece of white paper

Collecting Data:

Set up waves on the surface of water by using your hand, or by dropping something into the water, or by disturbing the surface in some other way. Can you observe wave length and wave strength?

Strike a tuning fork and allow it to vibrate in the air. What is the pitch of the sound that it makes? This is its wave length. Can you increase its wave strength? How?

Strike it again and allow it to vibrate in the water. Can you see waves that it sets up in the water? How does the wave length of these waves compare with that of the waves you set up with your hands?

Hold a *prism* in bright sunlight. Allow the light that passes through it to fall on a piece of white paper. The colors that you see are called a *spectrum*. The prism has separated the sunlight into the different *wave lengths* that are in it. Can you see the colors in the following order:

Red
Orange
Yellow
Green
Blue
Indigo
Violet

How many of these colors can you see? The red light has *longer* wave length. The violet light has *shorter* wave length.

Waves That You Can't Hear or See

Since wave length is the distance from one wave to the next, waves with longer wave length such as red light are farther apart. Waves with shorter wave length such as violet light are closer together. Only the waves *between red and violet* can be seen with our eyes. There are some waves, however, that are related to light waves,that you cannot hear or see.

There are waves which are *shorter* than violet light. These are called *ultra-violet radiation*. They are abundant in sunshine, even though we cannot *see* them. They are what causes a sun-tan. What other things can they do? Why? X-rays are even *shorter* than ultra-violet. What can these waves do?

There are other waves that we cannot see which are *longer* than red light. These are called *infra-red* radiation. We can feel them as *heat*, even though we cannot *see* them. Other waves are still longer than infra-red. These are *radio waves*. Patterns in these waves, formed by variations in *wave length* and *wave strength*, are used in radio and television communication.

Materials and Equipment:

Radio, record player, or television set

Sheet of typing paper (8½" x 11"), not folded or distorted

Two large tin cans the same size, and a long string

Compound microscope

Phonograph record

Collecting Data:

You can *hear* sound waves. Can you also *feel* sound waves?

Use a sheet of 8½" x 11" typing paper. Hold it with one hand between your thumb and forefinger at a point in the middle of the top edge. Hold it suspended in front of a radio, record player, or television set that is playing *loudly*. Then, with the other hand, place the tips of your fingers *lightly* against the middle of the sheet of paper on the side away from the sound source. Can you feel any vibrations? Can you feel any differences or patterning in the vibrations?

What is the larynx of a human being? Where is it located? How does it work? Place your finger tips against the skin over the larynx of a person who is speaking. Can you feel any vibrations? Can you feel any differences or patterning in the vibrations? How can deaf people learn in this way to understand a person speaking?

Did you really feel sound waves on the paper or on the skin over the larynx? Or did you feel vibrations in the paper and the skin caused by sound waves striking them? Put your hand in front of the radio, record player or television set without the paper. Can you feel the sound waves directly on your skin? Does the sound wave pattern have to be transferred to something else before you can feel it?

Make a can-and-string telephone. Punch a hole in the bottom of each of two large tin cans. Make the holes only large enough for a string to pass through. Tie a knot in the string on the inside of the hole in each can. Leave the cans connected by a long straight string. Talk into one can and have a partner listen in the other can. Does the string carry the sound wave patterns from one can to the other? Try different lengths of string to see how far the sound wave pattern can be carried in this way. Does the sound wave pattern of your voice cause something else to vibrate with the same pattern, and then does this in turn cause the string to vibrate? How are the vibrations of the string carried to your partner's ear at the other end? How many transfers of pattern take place between your voice and your partner's ear?

Follow-Up:

When a human voice or a musical instrument makes a sound wave pattern, the sound waves carrying the pattern are transmitted through the air. Can a sound wave pattern be transmitted through a solid substance, such as a railroad rail? Can you think of an experiment which you might try in order to find an answer to this question?

When you hear a person speaking or singing on radio or television, or on the telephone, how is the sound wave pattern transmitted? Is it carried directly through the air or along a wire? What carried it? Are transfers of the pattern involved?

A light wave pattern may be preserved permanently in a photograph or a motion picture. How is the light wave pattern transmitted when you watch on television a scene that is happening far away? Are transfers of the pattern involved?

Examine the surface of a phonograph record under the low power of a compound microscope. Be sure that a strong light is shining on the surface of the record when you examine it. Observe the grooves. Are they all alike? Follow a single groove. Is it the same at all points? Can you see evidence of a pattern in any of the grooves? What form does the pattern take? What is the relation of the pattern in the groove on the record to the original sound wave pattern? What is the relation of the pattern in the groove to the sound wave pattern that is produced when the record is played?

In what different ways can sound wave patterns be recorded and later be reproduced? What is the relationship between the original sound and the reproduced sound? How is the pattern transferred from one thing that carries it to another?

What is meant by frequency? What is meant by amplitude?

LABORATORY EXPERIENCE E.2.c.

We Are What We Are Because ---

Introduction:

This experience is going to be entirely introspective (this means "to look inside"). You are to look thoughtfully at yourself, not only in a mirror which reflects your physical appearance, but also at yourself as you think you are. Consider why you are "this way."

Materials and Equipment:

Paper and pencil for "doodling, if you are one of those people who can think better with a pencil in your hand.

Collecting Data:

Many of your physical characteristics are the result of the inheritance of certain genes (hereditary determiners) from your parents. Which of your physical characteristics: eye color, hair color, curly, wavy or straight hair, nose shape, mouth, ears, height, body build, weight, and so forth, did you apparently inherit from your mother? From your father? From your father's parents? From your mother's parents? From both sides?

Which of your physical characteristics have been affected by factors in your environment? Is your weight dependent on your body build, or is it influenced by your failure to eat an adequate breakfast each morning? What has been the effect of your mother's good cooking? What about your like or dislike for "between meal" snacks? What environmental factors could have influenced your height? What other physical characteristics (hair color, skin color, and so forth) may be influenced by environment?

Were you a thumb-sucker when you were younger? Did this affect the shape of your mouth? Are you a nail-biter? How does this affect the appearance of your hands? How does exercise or lack of exercise influence your physical characteristics? What about diseases? Scars left by inoculations? By surgery? By accidents? You can probably think of many other environmental factors that have influenced you physically.

Let's think about your successes or failures in school. Did you inherit your ability or inability to read? Or were environmental factors of more importance? Do your parents read very much? Did they read to you? Did they provide books for you? Newspapers? Magazines? Did failure to learn to read in first grade completely discourage you? Did you consider reading necessary or unnecessary? Very important? Fun? Did your attitude toward reading influence your achievement in reading? In other subjects?

You have probably heard people discussing someone's I.Q. What does this mean? Is it entirely inherited? Partially inherited? Not inherited at all? Can environment change a person's I.Q.? How? How much?

More recently a great deal has been said about P.Q., the "persistency quotient." Another term for this is "stick-to-it-iveness." Do you inherit your P.Q. or is it dependent on your environment? Entirely? Partly? Not at all? How are success in school, I.Q. and P.Q. related. Did you ever read or hear the story of The Little Engine That Could? Why did the little engine succeed?

Has you success (or the lack of it) in some school subjects been affected by such a statement as, "You're just like me; I always had trouble with math." Is "trouble with math "inherited? Entirely? Partly? Not at all? What about musical ability? Artistic ability? How much is your success dependent on your attitudes? Are attitudes inherited? Entirely? Partly? Not at all? Can attitudes change?

Follow-Up:

Your success, your self-concept, your heredity, and your environment are such a tangled web of interdependence that no one can completely separate them. Only as you begin to look at yourself can you understand one of the most important ideas of science: that the interrelationship of patterns of inheritance and patterns of environment make you what you are.

E.3. Idea That Frames of Reference Determine Relationships

Idea Bridge: Relativity and Common Sense

How things look to you depends on how you look at them. And how you look at them depends on where you are, when you are looking at them, and how much they mean to you. A loaf of bread looks different to a man who hasn't eaten for three days, and a man who has just finished a big Thanksgiving dinner. We have already seen (B.2. Idea of Quantification) that the relative importance of a particular measurement changes, depending on how it is used, and what it is used for.

What we are really talking about is relativeness or frames of reference. We use this Idea all the time, but we usually don't bother to give it a name. It has been given mathematical expression in the Theory of Relativity. This has to do with the relationships of velocity, time, and mass in the physical universe. Don't let this frighten you. There is a common sense, non-mathematical aspect of relativity which you can readily understand, and for which you can find many every-day examples. It can be expressed simply this way: "things have the properties they do because of where they are, and when they are in relation to other things, rather than because of what they are." We will examine some laboratory experiences in relation to this Idea.

LABORATORY EXPERIENCE E.3.a.

What Do We Mean By "Where?"

Introduction:

What do you mean when you ask where something is, or try to tell someone where something is? The only way that you can answer a "where" question is to describe the position of the thing that was asked about in relation to other things. It is "near to this," or "on the far side of that," or "in front of something", or"behind something else." What other words can you use to indicate position?

When the thing that you are describing is moving, and the other things that are near it, or on the far side of it, or in front of it or behind it, are also moving, the relationships are more complex.

When we tell where something is, what we are really doing is placing it in a frame of reference. We are describing its position in terms of its relationships.

Materials and Equipment:

Three blocks of wood the same size, with a string attached to each.
Label the blocks "A", "B" and "C".

Florence flask

Wax pencil

"Sticky" dot of paper

Collecting Data:

Try to describe where something is without referring to anything else. Can you do this? See if you can figure out a way to do it.

Now use two blocks of wood with strings attached, labeled "A" and "B". Pull the two blocks toward one another. Describe the position of "A" with reference to "B". Pull "A" alongside "B"; then past "B", and then beyond "B". Continue to pull the two blocks in opposite directions. How does the description of "A's" position in relation to "B" change: (1) when "B" is approaching, (2) when "B" is alongside, (3) when past? How would you describe "A's" position from moment to moment as they move. If you were describing"B's" position in relation to "A" would your description of "A" fit "B" also, or would you have to make a different description? If a different one, how and why would it differ?

Now introduce a third block "C" which is drawn across the paths of the first two blocks. You will need a partner to help you with this. Describe the position of "A" as it moves in relation to "B" and "C" which are also moving. Describe the position of "C" as it moves in relation to "A" and "B". Will the description of the position of "B" as it moves in relation to "A" and "C" be different from that of "A" in relation to "B" and "C"? Why or why not?

Follow-Up:

Try moving one of the blocks up-and-down in relation to the other two. Describe their positions in relation to one another.

LABORATORY EXPERIENCE E.3.b.

Illusions

Introduction:

We can be confused by our senses if our frames of reference confuse us. Did you ever hear the story of the blind men and the elephant? Three blind men felt of an elephant. Each one felt of a different part of the creature. One felt of its tail, another felt of its side, and the third felt of its trunk. The first one described the elephant as a kind of rope. The second described it as a wall, and the third as a tree. Each one described what he felt by comparing the part of the animal that he felt in terms of something that he already knew. All three were confused by their frames of reference.

Materials and Equipment:

Rulers

Diagrams

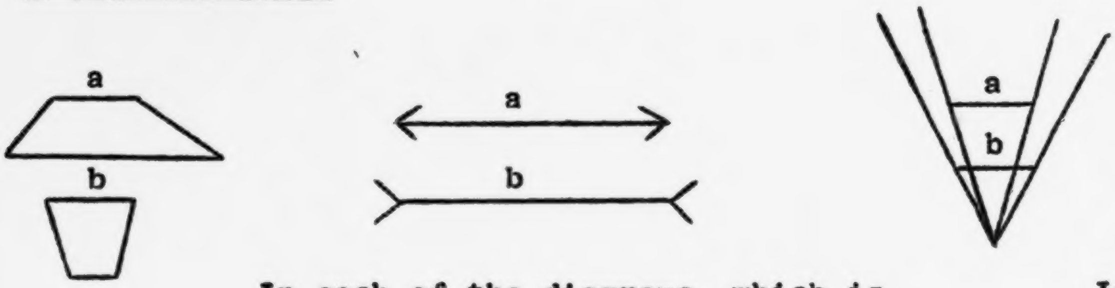
Pans

Hot and cold water

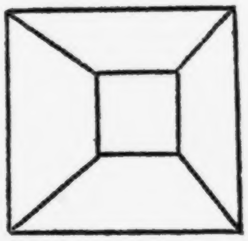
Raw vegetables

Musical instrument

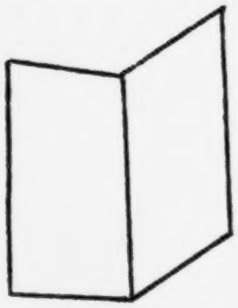
Collecting Data:



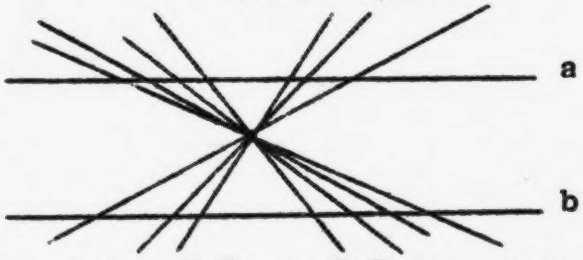
In each of the diagrams, which is longer, line "a" or line "b"?



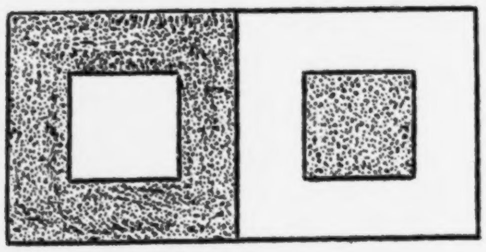
Is the inside square in front of or behind the outside square?



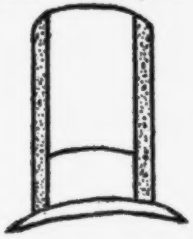
Does this book open toward you or away from you?



Are lines "a" and "b" parallel?



Which is larger, the inner black square or the inner white square?



Is the hat taller than the brim is wide?

Answer each question first by inspection. Then check your answer wherever possible by measurement. In each case what is the frame of reference that confuses you when you look at the diagram? Find other optical illusions in books. What is the frame of reference in each case? Examine some psychodelic prints. Do they appear to move? Why?

Follow-Up:

You can be confused by senses other than sight. Place one hand in hot water and the other hand in cold water for several minutes. Then put both hands into luke warm water. Does it feel the same to both hands? Why or why not?

Close your eyes and hold your nose while someone puts a piece of raw potato, carrot or rutabaga in your mouth. Can you identify which raw vegetable it is? Why or why not? Is this due to lack of a frame of reference, or simply the limitation of your sense of taste? Any other possible reasons?

Have someone play three successive notes on a musical instrument (B, C, C#, or G, F#, F). Is the last note highest or lowest in pitch? Now have him play just one of the three notes. Is it the highest, lowest, or middle one? Why is it harder to tell? Perhaps you know of someone who has "perfect pitch". What does this mean so far as frames of reference are concerned?

LABORATORY EXPERIENCE E.3.c.

How Do We Know Where We Are On The Earth?

Introduction: It is possible to use any object as a frame of reference if a reference point and a direction are identified. "I live two blocks east and one block north of the northeast corner of Main Street and Broadway." This statement gives a reference point and a direction.

But what if you were on a ship on the ocean with no land in sight? What could you use as a reference point? How could you tell direction? In this experience we will develop several different kinds of reference points, and find how to describe directions from them.

Materials and Equipment:

Florence flask

Wax pencil

Collecting Data:

Use the round bowl of a Florence flask as a globe in your hand. Hold the flask by the stem. Imagine that the round part is like the earth. Stick a small dot of paper on the globe. How could you tell someone across the room or behind a screen where the dot is? You need a frame of reference just as early navigators of the ocean did. What did they do?

Use a wax pencil and mark a straight line on your globe. Where would you draw one so you could tell the other person to draw the same line? What additional lines do you need to locate the dot of paper? What is latitude? What is longitude?

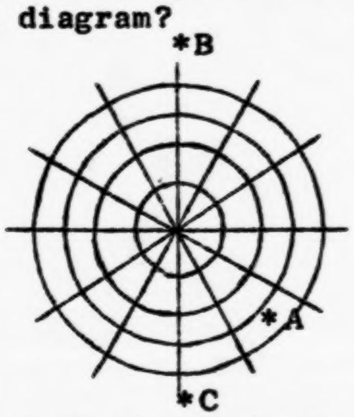
Early navigators felt the need for a prime meridian. What is a meridian? What is a prime meridian? Could you describe the location of your dot more accurately if you drew a prime meridian on your globe? Where would you put it?

What about more lines? What would you call them? How would you number them? Try locating the dot by these frames of reference that you have made. How does a navigator give his location?

The placing of parallels of latitude and meridians of longitude on a flask will give you the idea of position without motion. In order to get the idea of motion, rotate the flask. Discuss the use of the sun and moon as frames of reference. Remember that the earth rotates on its axis, and revolves around the sun. The moon revolves around the earth. Revolution added to rotation further complicates the relationships that require frames of reference to describe them.

Look at the midpoint of the bottom of your flask. Do all of your meridians meet at this point? On a globe, what would this point be?

If you flattened out all of your parallels and meridians on a piece of paper, would it look like this diagram?



What direction is Point A from the center? Point B? Point C? How could you describe the location of each point when they are all the same direction from the center? How far from the center is each point? Devise your own names for the frames of reference that you use. If you were standing at the South Pole, would it be possible to walk 100 paces to the east? West? South?

This type of diagram (map) is called a polar projection. It is used for navigation by pilots and astronauts. Why?

Follow-Up:

Find out about other projections that put the globe frames of reference or coordinates on flat paper. How are these related to map making?

If we think of the sky as a bowl, we can use celestial coordinates in locating heavenly bodies. Find out how these are named and numbered, and how they are used. Examine a star map.

Are there coordinates for the moon? For the planets? How would you locate a point where a lunar landing ship lands? How would you describe the location of a particular crater on the moon? What about the side of the moon that you cannot see?

E.4. Idea That Interdependence Consists of Relationships

Idea Bridge: Everything is Dependent on Something Else

One of the most important ideas that science has contributed to our thinking is that of interdependence (things depend upon each other) and interrelationships (things are related to each other). There is nothing in the universe that stands alone. Everything must be studied in its natural setting. If you take it out of its setting, it is not the same thing, any more. Everything that we know forms a part of a part of a "picture." This in turn, is part of a larger "picture," and this of a still larger "picture." This is true all the way out to the ultimate boundaries of the universe, if it has any boundaries.

Plants and animals in nature form communities. How are plants and animals dependent on each other? Plant-animal communities cannot exist outside of a particular environment or habitat. This environment includes such physical factors as temperature, relative humidity, light, air pressure, air movement, rainfall, soil, and length of season. It also includes the other plants and animals with which a particular plant or animal lives.

Not only are plants and animals affected by one another and by the physical environment, they also change the physical environment. The temperature, humidity, wind, and light on the forest floor are all modified by the forest itself. Many of the animals and plants of the forest floor could not exist without this modification. The kinds of trees that grow affect the acidity and alkalinity of the soil. This in turn helps to determine what kinds of plants can grow beneath the trees. Think of other examples of how living things affect their physical environment.

Many of the factors of the physical environment change in relation to one another. Pressure varies with depth. Temperature varies with pressure. Rate of erosion varies with slope. The evaporating power of the air depends upon several simple physical factors which interact to produce a single complex factor. If a living organism, such as a snail, a frog, an insect, or a man is taken out of its natural setting, or is changed from one setting to another, it behaves differently. It is really not the same organism anymore. The old descriptions of how it lives and acts do not apply any longer. Can you think of any examples of this kind of thing that apply to people? What about the behavior of children when they are away from home? What about adults in a new social situation? Do they behave as they normally do?

What would have happened if your parents had not moved to the place where you now live? You would not know the same people that you now know. They would be different and you would be different, too. The event of your parents' move into your present home brought about other events that would not have happened at all. Try to think what might or might not have happened if they had moved somewhere else.

There is nothing that is not influenced by other things. Try to think of something that really stands alone and is unaffected by other things. Can you do so? What about a stone? A chair? A day? A piece of chalk? A star? Try to think of all of the influences that affect any one thing. Then try to think of all of the influences that affect those influences? Try to find a stopping place. Can you?

LABORATORY EXPERIENCE E.4.a.

A Pond Infusion Culture

Introduction:

Plants and animals live in communities in nature. These are much like human communities. In human communities different persons do different kinds of jobs. Yet all of them depend on one another, and the life of the community as a whole depends on all of them.

You can set up a model plant-animal community in the form of a balanced aquarium (Laboratory Experience D.6.d.) and watch the interdependence of the different kinds of living things in the community. You can see their interrelationships at work.

In a human community, if there is a big change such as might take place if a new industry is started, the interrelationships change too. You can set up a model of this kind of change in terms of a plant-animal community and study it in the laboratory. You can watch the interdependence develop as the community changes.

This laboratory model of a changing community is called a pond infusion culture. It is a small aquatic (water) community. When it has completed its adjustment to the changed conditions of the laboratory it becomes a little balanced aquarium, which has only microscopic animals and plants in it.

You will start the culture with water and dead plant material from the edge of a pond or stream pool. Many kinds of microscopic plant and animal life are brought in with the water and dead plant material. In the pond or pool there are also other larger animals and plants, but you will bring in only the microscopic ones.

In the pond or pool there is a great deal of light, and the temperature goes up and down with day and night. Also the wind ruffles the surface of the water and mixes oxygen from the air with it. The oxygen becomes dissolved in the water.

When you bring a jar of this material into the laboratory, there is only light from the window. The temperature stays more nearly the same day and night. There is no wind to mix oxygen with the water. Some of the microscopic animals and plants can survive and multiply under these changed conditions. Others die because they cannot live under the changed conditions. Decay sets in in the dead plant material and the dead bodies. Bacteria which cause decay increase in numbers. Then the organisms that eat the bacteria increase also. Finally, after a long series of changes the little community comes to a balance under the new conditions.

Materials and Equipment:

Quart jars

Compound microscope

Glass microscope slides

Plastic cover slips

Medicine droppers

Bathroom paper for cleaning microscope slides and drying cover slips

Paper towels for drying slides

Reference books containing pictures to help in identifying microscopic animals and plants

Setting Up a Pond Infusion Culture

Fill a quart jar about three-fourths full with dead and living plant material from the edge of a pond or stream pool. Include some floating and submerged green vegetation and some of the dead vegetation from the pond bottom. Be careful not to include mud. Then fill the jar to a point about one inch from the top with water taken from where it has been stirred up. In this way you will get a good sample of the microscopic aquatic plants and animals in this environment.

A pond infusion culture consists simply of a jar of material obtained in this way, and allowed to undergo the natural changes that occur during a period of days or weeks because of the changed environmental conditions to which it is exposed in the laboratory.

The culture should be placed in a window in the laboratory but it should not be allowed to stand in direct sunlight. It should be moved as little as possible. The same side of the jar should be kept next to the window at all times. Why?

Collecting Data:

A pond edge sample which is collected in this way will contain a very great variety of kinds of microscopic organisms. They will not all appear, however, if you look at the material as soon as you get it in the laboratory. This is because it has been stirred up by the collecting process. It has not had time enough to reorganize itself into a community in which the organisms are responding to the environmental factors (light, dissolved oxygen, temperature, et cetera) as they exist in the laboratory. Therefore, you must allow it to stand for about 24 hours before you study it.

When you take a sample from the culture jar for study under the microscope, use the following procedure: Scrape the end of a medicine dropper against the side of the jar nearest the window. Move it up and down through the top film of the water as you do this. Fill the dropper about half full with water from this area. Do this by releasing the pressure on the bulb slowly. Most of the living organisms are concentrated in the top film of the water on the side of the jar nearest the window. Why?

In addition to any other advantages in taking samples in this way, there is the advantage of uniformity. Samples taken in the same way each time the culture is studied make a comparison of results possible. If you wish to take additional samples from other parts of the culture, using different methods, you are free to do so. Such samples may be compared with the ones taken in the standard way.

The microscopic animals and plants that you find may be grouped under a few categories:

(1) Protozoa. These are one-celled animals. You may see representatives of three groups:

- (a) Flagellates. These move through the water by means of a whip-like organ called a flagellum. This produces a zig-zag type of movement in which the front end of the animal moves from side to side as it goes forward. There may be more than one flagellum. These project from the front end of the animal, but you are not likely to see them.

- (b) Ciliates. Most of these move smoothly forward through the water by means of many hair-like projections which cover the body. These are called cilia. They act like little oars in moving the body through the water. Ciliates are among the most common of the protozoa in the culture. Most of them feed on bacteria.

- (c) Rhizopods. These are rare in the culture. They move by means of temporary finger-like projections called pseudopodia. Some of them have shells which encase their bodies.

(2) Microscopic metazoa. These are many-celled animals. They range in size up to those which can be seen without the microscope. Some of them are:

- (a) Microcrustacea. These are related to the crayfish, the shrimp, and the lobster, but are microscopic in size.

- (b) Insect larvae. These are the young forms of small kinds of flies, beetles and other insects that spend their lives in or near the water

- (c) Worms. These are generally aquatic annelid worms. They are related to the earthworm. They have segmented bodies that you can readily see through. They have long hairs called setae along the sides of the body.

- (d) Rotifers. These are small organisms which generally look like minute worms with cilia around their heads. They are about the size of protozoa but actually they are many-celled. They extend their bodies and draw them back, and they may appear to be attached at the rear end.

(3) Green algae. These are microscopic green plants. They generally consist of a single cell or a chain of cells. Those which live in the culture include:

(a) Filamentous green algae. These are long strands made up of many cells. They appear as long, green hairs, which look like trains of boxcars under the high power of the microscope.

(b) Single-celled green algae. Sometimes these move around. Sometimes they stay still. Sometimes they appear as a gelatinous mass of material. If they appear as a mass the individual cells may be difficult to distinguish, even with high power.

(c) Colonial green algae. These appear as green balls of cells which may be moving by rolling over and over in the water. The individual cells are easy to distinguish.

(d) Blue-green algae. These are generally smaller than the green algae. They can be recognized by their bluish-green (as contrasted to yellowish green or bright green) color. They may be either long, hair-like strands in which the individual cells are difficult to distinguish, or they may be in gelatinous masses.

(e) Diatoms. These are single cells or double cells. They are yellowish or straw colored, or sometimes brown.

(f) Desmids. These are double cells, large, and grass-green in color. They are pointed at each end, either curved "half-moons" or straight.

(4) Bacteria. There are three main types: rods (bacilli), corkscrews (spirilla), and circles (cocci). All are just at the lower limit of vision with the low power of the microscope. The bacilli may be in the form of long, hair-like chains. The cocci are the smallest. They may be in chains (streptococci), bunches like grapes (staphylococci) or doubles (diplococci). All three types may also appear as single cells. The bacilli and spirilla may be moving or non-moving. The cocci do not move.

Ask your teacher to help you with identification of the things you see. If you wish to learn about them in greater detail the following books will be helpful:

1. Eddy, Samuel, and Hodson, A.C., Taxonomic Keys to the Common Animals of the North Central States. Burgess Publishing Company, Minneapolis, Minnesota, 1955.

2. Needham, James G., and Needham, Paul R. A Guide to the Study of Freshwater Biology. Holden-Day, Inc., San Francisco, California, 1962.

3. Jahn, T.L., How to Know the Protozoa. William C. Brown and Company, Dubuque, Iowa, 1949.

4. Ward, H.B., and Whipple, G.C., Freshwater Biology. John Wiley and Sons, New York, 1918. (Second Edition, W.T. Edmondson, editor, 1959).

Any other good reference book on microscopic aquatic life will be useful. Any reference used, however, must contain pictures or sketches of the common microorganisms. Keys are necessary for detailed identification, but they are relatively useless for the type of recognition necessary in this laboratory experience. It is better to leave some organisms unidentified than to "lose the forest while studying the trees." The goal of this experience is to understand relationships in the community, and not to identify organisms. You should give your main attention to the kinds of organisms that are numerous, and pay less attention to those that appear only occasionally or rarely.

Examine the culture each day during the first two weeks. After the first two weeks, examinations once a week will be enough to observe the slow changes that are occurring. The changes that occur during the first two weeks are rapid and interesting. After this you see much the same things each time you look at the culture.

Watch for the growth of a green scum on the side of the jar nearest the window. When does this begin to develop? This indicates that green plant activity is beginning to take place and that the community is beginning to reach a state of balance. Why? You may stop your observation at this point if you wish. You may also, however, wish to examine an old culture jar that has stood for a year or more. What additional changes have occurred in the old jar? Why? How long do you think it will stay this way? Why?

In general, the principal organisms in the culture during the first two or three days are the ones that are common in the samples taken directly from the pond. These include microscopic metazoa, green algae, diatoms, blue-green algae, and protozoa in small numbers. After a few days, the algae, the microscopic metazoa, and some of the kinds of protozoa become fewer in number and disappear. Decay sets in, bacteria multiply, and can be seen in large masses around decaying vegetation. At the same time the ciliate protozoa which feed on bacteria become very abundant. This stage may last for several weeks.

Finally, as decay runs its course, the bacteria and bacteria-feeders become fewer. The green and blue-green algae become abundant again. Some of the microscopic metazoa that have been able to live through the changes are again seen in small numbers, and the culture slowly arrives at a balance.

Follow-Up:

When the culture jar has reached a balance, a comparison with a larger balanced aquarium is interesting. How is the culture jar similar to the larger balanced aquarium? How is it different? Why? How are both of them similar to the plant-animal community of a pond or lake? How are they different? Why?

How is the succession process that goes on in the pond infusion related to some of the methods of purification of a city water supply? to some of the methods of treatment of sewage? Visit a city water system and a sewage disposal system if you can, and see some of these processes in operation.

LABORATORY EXPERIENCE E.4.b.

A Field Trip in the Laboratory

Introduction:

Plants and animals depend on one another, and on the factors of their physical environment. Some of these factors are light, temperature, moisture in the soil, moisture in the air or humidity, air movement. The interrelated organisms that live in a particular place or habitat make up a community. It is possible to make a model of the relationships that exist in a plant-animal community. This model will show the interdependence of living organisms, and their dependence on their physical environment.

Materials and Equipment:

Ball of string

5" by 8" cards

Masking tape

Thumb tacks

Collecting Data:

Select a habitat where plants and animals live. List as many kinds of plants and animals as you can that live in this habitat. Think of the interrelationships that exist among the different organisms, and the physical environmental factors on which they depend.

Prepare a 5" x 8" card for each kind of plant and animal that you have listed. The card should include the common name of the organism, and the principal physical environmental factors that affect it directly (for example: goldenrod, sunshine, rainfall, and so forth; or land snail, moisture, shade, and so forth).

Arrange the cards in a convenient fashion on the top of a table, or on the floor. Fasten them with masking tape or with thumbtacks.

Run a string from each card, representing an organism, to each card representing another organism to which it is in any way related. The relationship may have to do with food, predation, cover, nesting site, or anything else that you can think of. Fasten the ends of the strings to the cards with single tabs of tape or with thumbtacks.

Make a list for each organism, including the names of all the other organisms to which it is related. Tell the nature of the relationship in each case.

Now vary or eliminate any single physical environmental factor (for example, rainfall, temperature, light) and find out by looking at the cards (1) what organisms would be affected directly, (2) what organisms would be affected indirectly (by the direct effect on organisms to which they are related), and (3) what the effect would be on each organism affected directly or indirectly. Keep a record. Do this for several environmental factors one at a time.

Now vary (increase or decrease in numbers) or take away any single kind of organism in the web of relationships. Find out by looking at the cards and the strings (1) what other organisms would be affected (a) directly, or (b) indirectly, and (2) how they would be affected. Keep a record. Do this for several organisms in your web of relationships.

Are some organisms more important to the community than others? What is meant when some organisms are called "key organisms?" Why? Try to define a plant-animal community, including both living organisms and physical environmental factors in your definition.

Follow-Up:

Of what does weather consist? Climate? What is the relationship between weather and climate? Why does climate remain the same from year to year for long periods? What would be the effect on plant-animal communities if climate did not remain the same? Have there been times when the climate changed? When? What happened? Is there any evidence for climatic change within the lifetime of one person? What about climatic cycles?

What is meant by conservation? Do people always mean the same thing when they talk about conservation? How is conservation related to plant-animal communities? What do we mean when we talk about destructive activities and constructive activities of man in relation to nature? Try to make your own definition of destructive and constructive activities. List as many of both kinds of activities as you can. Try to make your own definition of conservation in terms of relationships.

LABORATORY EXPERIENCE E.4.c.

Relationship of Acidity and Alkalinity to Yeast Activity

Introduction:

Nothing exists alone. Every living organism and every bit of non-living matter interacts with the things around it. Nothing stands still either. Everything in the universe is constantly changing. We can demonstrate that the kind and quantity of change which occurs in an organism is dependent on conditions of the environment.

One way that we can see this is by watching and measuring the amount of yeast activity, in terms of the amount of carbon dioxide (CO_2) produced, in environments of varying acidity and alkalinity. A series of these environments can be constructed from extreme acidity to extreme alkalinity. The measurement of acidity and/or alkalinity is called pH.

Materials and Equipment:

One cake or envelope of dried yeast (Red Star or Fleischman's)

Test tubes without rims: 2 sizes--13mm. x 100mm. and 18mm.x 150mm.

Test tube rack

pH paper, pHydrion paper dispenser AB pH 1 to 11 (a standard lab item)

Test tube brush

Solutions: 6N NaOH* and 6N HCl*

Table sugar (sucrose)

Simple balance for weighing in grams

Graduate cylinder, 100 ml. (1 milliliter equals 1 cubic centimeter)

Centigrade thermometer

Five beakers or small jars

Two quart jars for dissolving sugar and yeast

Millimeter rule

Aluminum foil for covering jars (if desired)

Wax pencil for labeling test tubes

Graph paper

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* To prepare a 6N solution of NaOH, dissolve 240g. of NaOh in enough water to make a liter. Since most commercial preparations of concentrated HCl are approximately 35 per cent hydrogen chloride, dissolve 600 ml. of concentrated HCl in enough water to make a liter.

Collecting Data:

Place yeast in 100 ml. of lukewarm water (approximately 37°C.) Stir to break it up and shake it well.

Weigh out 50 gr. of sugar and dissolve it in 500 ml. of water at approximately 37°C. (or lukewarm to finger). This is approximately a 10 per cent solution. Add a dropper full of the yeast to the sugar solution. Stir well.

From this point students should work in small groups. There should be five such groups, each working with 100 ml. of solution. Each group will obtain and work with a solution of different pH (pH 1, 4, 7, 9 and 11). A range of difference such as this is an example of a gradient. A pH of 1 is very acid, a pH of 7 is neutral and a pH of 11 is very alkaline (or basic). This gradient therefore ranges from extreme acidity to high alkalinity.

Each group should follow these directions:

1. Put 100 ml. of yeast-sugar solution in a beaker or small jar.

2. Adjust to the desired pH by adding NaOh or HCl, one drop at a time until the pHydrion paper indicates the desired alkalinity or acidity.

3. Put 20-23 ml. of this solution into each of three of the larger test tubes. If you pour a measured amount into one test tube, you may simply pour the others to match it.

4. The next step is tricky. Practice the procedure with plain water until you are sure that you can do it before attempting it with the yeast-sugar solution.

   Fill the small tube with liquid from the 20-23 ml. quantity in the large tube.

   Capsize it quickly in the large tube so that it is completely submerged, open end down.

   Hold your thumb over the open end of the large tube and turn it upside down, so that all of the air in either tube is collected in the bottom (now turned upward) of the large tube.

   Carefully turn the large tube upright in such a way that the bubble of air passes upward past the open end of the small tube without entering it.

   The small tube is now completely submerged, open end down in the large tube, with no air in it.

   Your yeast is now ready to carry on activity.

5. Label the test tubes according to pH, and place them upright in the test tube rack. Leave them at room temperature for 24 hours.

6. At the end of the 24-hour period, measure with millimeter rule the amount of gas produced in each tube. The gas produced is CO_2, an end-product of the oxidation of the carbohydrate, sucrose. The amount of gas produced is an index to the amount of yeast activity (fermentation) which has occurred.

7. Compute the average amount of gas produced in the three tubes of the same pH.

Pool the data for all groups and record on graph paper, plotting millimeters of gas against pH value.

What is the relationship of yeast activity to acidity and alkalinity? What is the best pH for yeast activity? Can you think of an explanation for this? Is the extent of yeast activity the same in each of the three test tubes with the same pH? Why is the experience more valid with three tubes of each kind rather than only one?

Follow-Up:

When you have determined the best pH for the activity of yeast, you may investigate the relationship of yeast activity to other chemical environments. Maintain the optimum pH, as you have determined it, and set up:

A gradient of nutrition using varying concentrations of sugar as a food source.

A gradient of salinity, using varying solutions of table salt (NaCl). Be sure to start with very dilute solutions at one end of your gradient.

A gradient of chlorination, using varying dilutions of commercial Clorox as a chlorime source. Here again be sure to start with very dilute solutions. Determine the killing point. How is this related to purification of water supplies?

Why is a gradient used in the case of each of these chemical environments?

Your original experience will produce measurable results more quickly if you use heavier concentrations of yeast to seed the culture. See if you can get measurable results in a single class period in this way. Try a gradient of yeast concentrations at the best pH.

LABORATORY EXPERIENCE E.4.d.

Evaporating Power of the Air

Introduction:

When we think of physical environmental factors, we generally think of them separately: temperature, relative humidity (moisture in the air), air movement (wind), atmospheric pressure, light. Actually, they are all interrelated in their action and on their effects in living organisms. Indeed, it is sometimes difficult to consider their effects separately.

Evaporating power of the air is a physical environmental factor that results from the interaction of several separate factors. These include temperature, relative humidity, air movement, and possibly others.

Materials and Equipment:

Thermometers (Centigrade or Fahrenheit)

Pan for boiling water

Electric fan

Hand fan

Rubber bands

Wide mouth jar

Plastic wrap

Device for holding thermometers erect

Small piece of woolen cloth

Eight ounce drinking glass

Nine inch pie pan

Sponge

Collecting Data:

Test a variety of temperatures in different locations, using two identical thermometers. Be sure to leave the thermometers in each place long enough to insure an accurate reading. How long is "long enough?" Why?

a. classroom
b. in the sun
c. near a radiator or other source of heat
d. just above a pan of boiling water
e. after fanning with a hand fan
f. in front of an electric fan

Do the two thermometers register identical temperatures in all cases? If not, is the difference the same in all cases? If it is the same, record this difference and use it as a correction factor in all later readings. If it is not the same, can you suggest why?

Wet a small piece of woolen or other heavy cloth and fasten it with a rubber band around the bulb of one thermometer. Support both thermometers in an upright position, side by side, about three inches apart. Be sure to keep the cloth wet while you are carrying on the experience. You now have a "dry bulb" thermometer and a "wet bulb" thermometer.

Record the dry bulb and the wet bulb temperatures in the same locations that you tested before. Be sure to leave them in each location long enough to insure an accurate reading. How long is "long enough" in this case? Why is there a difference between the dry bulb and the wet bulb temperatures? Where do you find the greatest difference between the two temperatures? Why? Where the least difference? Why?

Record the dry bulb and the wet bulb temperatures after hand fanning and in front of the electric fan.

a. in the sun
b. near a radiator (or other source of heat)
c. over a pan of boiling water

Compare these readings with the ones obtained in the same locations without the fan. What differences do you observe? What conclusions can you draw? Why?

Starting with a freshly wet cloth on the wet bulb thermometer, let the thermometers stand at room temperature until the cloth is dry. Record the temperatures on both thermometers every five minutes on a single sheet of graph paper. What is the relationship between them? Do the same thing in front of the electric fan. Record the results in the same way. What is the relationship between the two sets of data? Why?

Put two or three inches of water in the bottom of a wide mouth jar. Cover the mouth of the jar with plastic wrap. Insert two thermometers, a dry bulb and a wet bulb, side by side, through two small holes (as small as possible) in the plastic wrap. Devise a means of holding them erect side by side, with the bulbs suspended above the water. Allow this set-up to stand in a warm place (in the sun or near a radiator) for several hours. What is the relationship between the dry bulb and the wet bulb temperatures? Why? Which of the locations used earlier is most nearly comparable to this situation? Why?

Fill an eight ounce drinking glass with water. Pour it into a nine inch pie pan. Refill the drinking glass with water. Allow both containers to stand at room temperature for 24 hours. Measure the amount of water remaining in each. What is the relationship? Why? Calculate the surface area of the water in the pan and in the glass at the start of the experience. How many times larger is the exposed surface of the water in the pan than in the glass? What relationship does this difference bear to the difference in amount of evaporation in the two vessels? Can you think of any factors that might enter into the situation to affect this relationship?

Follow-Up:

Summarize what you have found out about the interrelationships of physical environmental factors involved in the evaporating power of the air. List the physical factors that you have studied. What factors do you think are involved in the evaporating power of the air other than the ones you have studied? What effect do you think these other factors have, and how do they enter into the picture? What do meterologists mean by the "comfort factor?" What does it include?

How is relative humidity measured? How is it related to the actual amount of water vapor in the air (absolute humidity)? Hold a sponge beneath the surface of water, and allow it to become completely filled with water. Then remove it fron the water and squeeze approximately half of the water out of it. Release the pressure on it and allow it to resume its natural shape. Explain how this constitutes a model which illustrates the condition of the air expressed by "50 percent relative humidity." Why does relative humidity increase with falling temperature? What is meant by dew point?

LABORATORY EXPERIENCE E.4.e.

Forest Edge Communities

Introduction:

Plants and animals never live alone. They are always associated with other plants and animals. Usually these belong to many different species. Organisms that live together influence one another. They make up the living environment of each other. The physical environment (temperature, relative humidity, air movement, light, soil, and so forth) influences the living environment, and is also influenced by it. The plants and animals that live together in a particular habitat, interacting with the physical environment, make up a plant-animal (biotic) community.

There are many different kinds of biotic communities. Some exist in water and are called aquatic communities. These include ponds, temporary pools, small streams, rivers, lakes, the ocean. Others exist on land and are called terrestrial communities. In any region that was originally covered with forest, one of the most common kinds of terrestrial communities is forest edge. It exists in many places besides the edge of a forest. This community has certain characteristics by which it is easily recognized. These characteristics indicate environmental conditions that determine the kinds of plants and animals that can live in the community.

Forest edge conditions always include:

(1) Partial or open shade, as contrasted to the closed shade of a forest and the open sunshine of a grassland.

(2) A mixture of vegetation types: trees, shrubs, vines, broad-leaved plants that grow up each year and die down with frost, and grasses.

(3) A tangle of vegetation, through which you will look for a path before you try to break through and make one.

Such conditions are ordinarily found at the edge of a woods (attached forest edge). They are also found in many other places. There are communities of forest edge type (a) in field borders, (b) along roadsides, (c) in brushy pastures and abandoned areas, and (d) in towns and cities; wherever people have planted trees, shrubs and grasses, or have allowed them to grow. Communities, which show forest edge characteristics but are not attached to a forest, are called detached forest edge. Most of them have been created by man, or have been allowed to develop in connection with man's uses of the land.

Materials and Equipment:

An attached or detached forest edge community

Collecting Data:

If it is possible for you to do so, visit the edge of a woods and look for the conditions of forest edge. Try to get a mental picture of what these conditions look like when they are attached to a forest.

Observe detached forest edge conditions. If you are in a rural area, look at roadsides, field borders, or abandoned fields. If you are in a town or city, look for detached forest edge conditions in parks, around dwellings, on school grounds, landscaped grounds around public buildings and industrial sites, in cemeteries. Where else do you think you might look for these conditions?

Examine urban waste areas for the general evidences of forest edge: railroad rights-of-way, the edges of parking lots, foundations of wrecked buildings, city dumps. Any others that you can think of? What evidences of forest edge can you find in these places?

Go into the center of a town or city, where there is very little that is apparent except buildings and pavement, and where at first glance there is no visible life at all except humans. Look for other living things. Are there any birds? What kinds? Any insects? What kinds? Look at cracks in the sidewalk and around the foundations of buildings. Do you find any other animals? What other kinds of animals do you think you might find if you could look inside buildings? In basements? In other hidden places?

What kinds of plants do you find in the city center? In what kinds of places do you find them?

Select an urban waste area within walking distance of your school, or study a portion of the school ground that is trampled and not cared for. Examine carefully as large a plot as possible, with definite boundary lines, and of a size that you can measure. Try to discover all of the kinds of plants and animals that are on it. Count or calculate the approximate number of each kind. With the smaller species, you may have to count the number in a small, typical area (for example, one square yard), and then calculate from this the number that you would expect to find in the total area.

What are the most abundant species of plants? Of animals? How is the number related to size? Are the smallest species always the most abundant? Try to account for the relative abundance of some species and the relative scarcity of others. Try to figure out the relationship of each species to the environment. To the community as a whole.

Scientific names, while desirable and useful if they are already known or can be obtained easily, are not really necessary for this experience. The goal of the experience is to study relationships rather than to identify animals and plants. Identification is a means to an end, rather than an end in itself. Common names, such as "spring beauty" or "thirteen-lined ground squirrel," or even assigned names, such as snail #1, snail #2, and snail #3, or "small lavender-flowered mint" will be all right if more detailed identification is not possible.

You may find the following method of tabulation helpful.

TREES

Name of Species	Number per Unit of Area
1. ----------	------------
2. ----------	------------
3. ----------	------------

SHRUBS

Name of Species	Number per Unit of Area
1. ----------	--------------
2. ----------	--------------
3. ----------	--------------

Continue with similar listings for Broad-leaved Plants, Grasses, Vines, and Other Plants.

In the same way list Birds, Mammals, Other Invertebrates, Insects, and Other Vertebrates.

You will find the following books helpful:

Rickett, Harold W., American Wild Flowers, Houghton Mifflin Company, Boston.

Petrides, George A., Field Guide to Trees and Shrubs, Houghton Mifflin Company, Boston.

Peterson, Roger Tory, A Field Guide to the Birds, Houghton Mifflin Company, Boston.

Lutz, Frank E., Field Book of Insects, G.P. Putnam's Sons, New York.

If you do not have these books available, any other field books or field guides that contain illustrations and descriptions will be helpful. The books listed above are particularly useful in the Eastern United States. In the Western United States or elsewhere it may be necessary to use regional field books or guides prepared especially for that area.

To what extent does the urban waste area that you have studied fulfill the general conditions of a forest edge community? What is the relationship of man to the area? What evidences of human influence and activity have you found? What do you think would happen to the area if the human influence were removed? Do you think that there are any animals that may live in or travel through the area that your study has not shown? Why?

Follow-Up:

Many of the plants and animals that are found in urban waste areas are not native to North America. They were brought in, mainly from Europe. Some of the plants are garden escapes. What are some of these? Others are commonly called "weeds." What is the definition of a weed?

Some of the animals are likewise European in origin. All of them are able to live in fairly close association with man. There is no good name for these animals. Sometimes they have been referred to as "animal weeds." A better term for them is "campfollowers".

See if you can find out which of the plants and animals that you have found are not native to North America? Why do you think they are found in this habitat?

Study other detached forest edge situations in the same detailed fashion that you have studied an urban waste area. Also study an attached forest edge community at the edge of a woods. What differences do you find between (a) the urban waste area, (b) other kinds of detached forest edge communities, and (c) forest edge at the edge of a woods? What are the kinds and relative importance of human influence in each one? Can man be considered a member of the biotic community?

LABORATORY EXPERIENCE E.4.f.

Interrelationships on Your School Ground

Introduction:

No matter how small or barren your school ground may be, you can find a wide variety of physical environmental conditions within it. Of course, if your school ground is large, with many kinds of landscaping and plantings, there will be an even greater variety. These physical conditions help to determine the plants and animals that are found, and what they do.

You do not need very much equipment to describe in a meaningful way the variety of physical environmental conditions that exist around your school. Careful observation with the tools that you have or can easily get or make will enable you to collect significant data and make valid comparisons.

Materials and Equipment:

Yardstick

Wooden stakes

Thermometers

Photographic light meter

Hand water sprinkler

Cylinders made from tin cans with the ends removed

Watch with second hand

Wooden dowel or pointed pencil

Small piece of woolen cloth

Rubber band

Candle

Ruler

Collecting Data:

Stake out plots one yard square in as many different kinds of places as you can find in your school ground. For example:

a. Center of grass plot away from shade trees
b. Near the trunk of a very large shade tree
c. Edge of grass plot near shrubbery
d. Under shrubbery
e. Unshaded area where grass has been killed by trampling

f. Unshaded area of bare ground that has been cultivated, so that the surface soil is loosened
g. Area near the foundation of the building on the north side, that is shaded for most or all of the day
h. Area near the foundation of the building on the south side, that is exposed to sunshine for most or all of the day.

If you do not have places like these use others, but set up as many as you can.

Study each of the plots that you have chosen. Teams of students may work together. In a team, the same person should be responsible for testing any particular environmental factor in all of the plots. Why?

Study the following factors in each of the plots. Choose a clear, sunshiny day for your observations, if possible. Keep records on a chart such as the one suggested on the following page.

Soil hardness. See how far into the soil you can push a wooden dowel or a pointed pencil. Try several places on each plot. Why? Is bare soil harder or looser than soil covered with vegetation? Does the kind of vegetation have anything to do with it? Explore the differences in soil hardness in as much detail as you can.

Soil permeability. Use a small juice can with both ends removed. Push this cylinder down tightly against or slightly *into* the soil surface. Try to do this in such a way that no water can leak out around the lower edges. Fill the can with water to the same level in each plot. How long does it take the water to soak into the soil? Use a watch with a second hand. Is the time different for different plots? Why? Is there a relationship between *hardness* and *permeability*? Why?

Temperature at soil surface. Place a thermometer with the bulb at the soil surface. If the plot is in sunlight, shade the bulb from the sun. Leave the thermometer for five minutes before reading it.

Humidity. This is the amount of water that is in the air. Use two thermometers, one of which has a small piece of woolen cloth fastened around the bulb with a rubber band. Wet the cloth covering of this thermometer. Place both thermometers side by side with the bulbs just at the surface of the soil. Fan the two thermometers until the temperature on each stabilizes. What is the difference in the temperature indicated by the two thermometers? Why? This difference is called the *wet bulb depression*. A great difference indicates that the air is very dry (low humidity). A slight difference indicates that the air has much water in it (high humidity). What form does water take when it is in the air?

What is *relative humidity*? It is determined from standard tables on the basis of the wet bulb depression. The wet bulb depression gives you a rough indication of relative humidity. Why does high relative humidity contribute to your discomfort on a hot day?

OBSERVATIONS OF MICRO-HABITATS

Location	Soil Hardness (inches of penetration)	Soil Permeability (time for absorption)	Temperature at soil Surface	Humidity (wet bulb depression)	Light	Air Movement		Precipitation	Animals		Plants	
						Direction	Force		Kinds Signs	Nos.	Kinds	Nos.

Light. Measure the amount of light at the surface of each plot with a photographic light meter. What is the unit of measurement for light? How is light related to other factors that you measure? Why? To what factors is it not related?

Air movement. Determine the direction of the wind as it blows against your face. Light a candle. By observing the behavior of the flame, estimate the force of the wind---strong, moderate, light, none--- (a) at the level of your head, (b) about a foot above the ground, (c) as near to the surface of the ground as possible. Record the (c) reading on your chart. Does it differ from the (a) and (b) readings? If so, to what extent does it differ? Why?

Precipitation. What is included under the term precipitation? You will need to record precipitation over an extended period. The simplest rain gauge is a straight-sided can. Cut the top out of a fairly large fruit or vegetable can. When you place it in your plot be sure that the sides are at right angles to the ground. Why? Be sure that the can is placed firmly on the ground, so that it will not be overturned. If you prepare a sufficient number of cans, all alike, you can put one in each of your plots. There may not be much variation in the amount of water that reaches the ground in different plots, but you should know if there is any variation, and try to determine the reason for it. From the standpoint of good scientific procedure, the possibility of variation should be checked. Why?

Leave the can in the plot for a week. Measure with a ruler the amount of water collected in inches and fractions of inches as soon as possible after each rain. Why "as soon as possible?" Keep a record. Calculate the total. If possible, leave the can for a longer period. Again calculate the total. Compare your results with the regional rainfall for the same period, as recorded by the nearest local weather station. How do your results vary from the regional rainfall? Why do you think this variation may have occurred?

If other forms of precipitation occur (snow and so forth) during your period of measurement, be sure to include these along with rainfall. How can you do this?

Imitate the effects of a hard rain on the surface of each plot by sprinkling a measured amount of water from a sprinkling can held three feet above the surface. Leave your rain gauge in place while you do this. How much "rainfall" did you produce? What differences do you observe in the effect of heavy rainfall on different types of surfaces? What about the effect of vegetative growth of different kinds? What conclusions can you draw with regard to soil erosion?

Animals. Note number and kinds of animals wherever it is possible to observe them. Remember that insects, worms, and larvae of various kinds are animals, along with mammals and birds. What larger animals (such as mammals and birds) would pass through or over the plots without affecting them? Can you observe any of these in the general area? What about signs of animals, such as damaged plants, tracks, or droppings? What about the effects of man as a very large animal?

Plants. Note the kinds of plants present in each plot. Note the number of kinds and the number of each kind. If you wish to collect a leaf or a blossom from each kind of plant for later identification, it is all right to do so.

What about larger plants (trees, shrubs, and so forth) that shade your plot, or whose leaves or seeds fall on its surface? What influence do these have? Is this influence the same at all seasons? Do they affect animals and other plants that live in the plot? How? Why?

Follow-Up:

What are the major differences in the physical conditions of the plots? What are the major differences in the inhabitants (plant and animal) of the plots? Are the inhabitants related to the physical conditions in each case? If you found some of the same kinds of plants in more than one plot, did they differ in size and form? If so, how and why?

Were some kinds of plants and animals more tolerant of habitat differences than others? What is it about these organisms that enables them to survive in the places where you found them? Consider a few of the plants and animals that are more limited in their distribution. What is it about them that limits them to the kinds of places where you found them? How do you think the range of tolerance of a species might affect its distribution over a large area such as a state or region?

What is meant by microclimate? How is it related to ordinary climate (macroclimate)? How do the microclimates of your plots differ? How do they differ from the general macroclimate of the region? To what extent do they differ? Compare your plots on cloudy days and sunshiny days. Which of the physical environmental factors that you have studied are affected by cloudiness? Which ones are not affected?

Project your findings on a continental scale. How does climate vary geographically? Why are certain plants and animals found in some regions and not in others? Are some organisms found just about everywhere? Why do you think this might be so?

LABORATORY EXPERIENCE E.4.g.

City Birds

Introduction:

There is bird life in the hearts of our cities if we look for it, and if we are willing to free ourselves from prejudice against the kinds of birds we find there. They are less beautiful, and often less clean. They are just as interesting, however, in their habits and relationships as the cleaner and more colorful birds of suburban backyards, parks, forest edges, forests and fields. City birds are a part of nature, too.

City birds are a part of the man-dominated plant-animal community of civilization, of which man himself is a part. They may be studied and admired for their ability to survive and flourish under conditions where other birds do not survive. Ability to survive is the measure of success in evolution in any place and time.

These city birds are available for anybody to see. Study them and see what you can find out about them.

Materials, Equipment, and Setting:

The setting is man-made. It consists of the streets and buildings which are characteristic of the city center. This includes business area, shops, apartments, and some public buildings. There may be small areas of school grounds and public parks.

A pair of field glasses (6x or 8x) will be a useful aid, but are not a necessity. Bird feeders and bird feed will make your observations more extensive and interesting, but all you really need to do is keep your eyes open, see the birds around you, and observe their activities.

Most of the birds that inhabit the city center are very common and easily identified: house sparrows, starlings, pigeons and a few others. If there is a small park or park-like area in the city center, you may see other birds during the migration seasons in the spring and fall. A few kinds may be winter residents only. It will be well if you have a bird book and can look up some of these.

Roger Tory Peterson, A Field Guide to the Birds, published by Houghton Mifflin Company, Boston, is probably the most readily available and easily used bird book. It is useful in North America, north of Mexico and east of the Rocky Mountains. You can get other bird books belonging to this same series for other areas where you may be. Many of the city birds, however, are the same wherever you go. Why is this?

Collecting Data:

Walk through the area that you have chosen to study. Walk slowly, preferably alone. If you are with others do not talk. Look and listen carefully. Do this several times, at different periods of the day. Repeat your observations on other days. Record in detail any data that you collect.

What birds do you see? How many different kinds? How many of each kind? What are they doing? Where do you see them? On or around buildings? In trees or shrubbery? On the ground? Are the different species seen alone or together? Always? Sometimes? If they are together are they perching together? Flying together? Feeding together? What kinds of sounds do they make? Pay special attention to these sounds, and learn what sounds are characteristic of what kinds of birds. Sometimes you can locate birds by the sounds they make, even when you cannot see them.

Does time of day have anything to do with the number of birds you see? The kinds of birds you see? Their activity? Do numbers, kinds, and activity have any relationship to weather? To season of the year?

Put up a bird feeder, or scatter feed on the ground or pavement in a spot where you have observed bird activity. Special bird feed is expensive and is not necessary. Ground corn or dried bread crumbs will do. Sunflower seed will be eaten by some birds. A piece of suet attached to a tree limb or shrub (out of the reach of dogs) will attract some kinds. What birds do you see feeding? What do they eat? Do they feed together? Is there any evidence of antagonism or rivalry between the different species? Do you observe any species around your feeding station that you haven't seen before?

Follow-Up:

See if you can find out the origin of the species of birds that inhabit the city center. How many of them are native American? How many are European? How did the European species get to this country? How did the species which are native American adapt to the presence and activities of man? Are they more or less numerous now than they were before there were cities for them to live in? Why? What would happen to the city birds (European and native American) if man and his cities were taken away?

Why are some people prejudiced against birds like the house sparrow, starling, and pigeon? Are other birds "better" than these? What makes one bird "better" than another? What is the difference between "good" birds and "bad" birds? "Good" and "bad" insects? "Good" and "bad" plants? What makes an animal or plant "good" or "bad?" What do you think about it? Why?

Choose another area of observation in a partially open, wooded section of a large park, away from buildings of any kind. Observe the birds that are there in the same way and for the same length of time as in the city center. What species do you see? Are there more species than in the city center? Are any of the species the same? Unless you are very well acquainted with birds, you will need a bird guide (Peterson's or some other) to identify some of those that you see.

What are the different species doing? What are their relationships with their habitat? With one another? With weather and other environmental factors? With time of day? With season of the year? What changes in kinds, numbers, and activity take place with the changing seasons? Were there similar seasonal changes among the birds of the city center? Why or why not?

Compare the forest or forest edge habitat with the habitat of the city center. What are the differences? Are there any similarities?

E.5. Idea That Heredity and Environment Are Necessarily Related

Idea Bridge: Heredity AND/OR Environment

When we talk about something being "caused by heredity" or "caused by environment" do we really mean what we say? We are quite willing to recognize that heredity plays an important part in the development of domestic animals and plants. We would not expect a Great Dane dog to produce a litter of terriers; nor would we expect seeds from a yellow tomato to produce plants that would bear red tomatoes. We recognize, of course that environment plays a part, too. We feed the livestock on our farms, train our horses and dogs, and fertilize our fields. All of these activities are part of the environment. We could not produce our domestic animals and plants without them. We know that heredity and environment *must necessarily interact*.

When we think and talk about people, however, we do not always remember this necessary interaction. We know that physical traits are inherited. These include things like eye color, height, type of body build, skin color, curly and straight hair. But are all of these due *entirely* to heredity? For example, from the standpoint of heredity, a certain boy would be able to grow to be six feet tall. When he is five years old, however, he is very ill, and that year he grows only half the normal amount. Normally he has been growing about two inches a year. That year he grows only one inch. He never makes up the inch that he did not grow in that particular year. There is a *time* and a *place* for each step in development. If it does not take place at that time, it never does take place. The boy's adult height is only five feet and eleven inches.

Could this be true of something like eye color? Yes, it could. Again for example, a child inherits the ability to develop dark brown eyes. The dark pigment is called *melanin*. It may be found in eyes, skin, and hair, making the person who has it dark. If the formation of the dark pigment should require the availability of a particular chemical *trace element* in the food, the lack of this trace element would stop the development of the pigment. We know about such a relationship in the development of the *thyroid gland*, and its secretion, *thyroxin*. If iodine is not present as a trace element the gland and its secretion do not develop normally. Something of the same kind could happen in the case of melanin.

The characteristics that we would like most to believe are primarily dependent on the environment are mental abilities and personality traits. These are the areas where it is most important that people be considered "equal." Society can do something about these traits through education and improved environment and make itself better in the process.

It is difficult, however, to see how even these traits could develop from environment alone. Any behavioral trait is dependent finally on the nervous system and/or the glands of internal secretion (*endocrine glands*). It has to have a physical basis in the anatomy and physiology of these body systems to exist at all. When we ask ourselves what kind of basis this is, we come to the structure, size, number, arrangement and chemical make-up of the nerve cells and secreting cells. All of these have to be based finally in heredity. This is what the individual starts out with.

What the individual starts out with is modified by (1) the environment of the embryo before birth, (2) the environment of childhood and youth, and (3) the everyday environment in which the individual lives. However, environment cannot create a characteristic from nothing. It has to have some basis on which to work. Likewise, heredity cannot operate in a vacuum. It has to have an environment in which to work. Therefore environment and heredity have to interact.

2

LABORATORY EXPERIENCE E.5.a.

Plants and Soil Nutrients

Introduction:

You may have read about how the world's population is increasing, and about the danger that exists that there may not be food enough to feed all the people before the next century is finished. So far, however, we have been burdened in this country and in other large food-producing countries with vast surpluses of certain kinds of food---more food than we know what to do with; more than we can either use or store. One reason for present-day food surpluses is the development of hereditary strains of crops like corn (maize) that give higher yields than the strains that were used a half century ago. Another reason has been the development of knowledge and practices having to do with the use of fertilizer. Thus our increased agricultural production has been based on a combination of improved heredity and improved environment.

You can see the interaction of these two factors in development by watching corn and bean seedlings grow under different conditions of fertilizer treatment.

Materials and Equipment:

Six flower pots, 6" in diameter

Soil

Sand

Balanced garden fertilizer

Teaspoon measure

Corn grains

Bean seeds

Foot rule

Graph paper

Dissecting microscope or hand lens

Biology or botany textbook

Collecting Data:

Before filling the flower pots, as directed below, place a small stone or a piece from a broken pot over the hole in the bottom of each pot. This will help drainage. Then fill each pot to within an inch of the top.

Fill two of the pots with sand, two with ordinary garden soil, and two with garden soil to which a teaspoonful of a balanced fertilizer has been added. Note: Measure out two of the potfuls of garden soil into a larger container. Add two teaspoonfuls of fertilizer, mix thoroughly, and divide the fertilized soil evenly between the two pots.

You have provided three different kinds of environment in which to grow corn and bean plants. Plant two grains of corn in each of the three kinds of pots. Plant two bean seeds in each of the three kinds of pots. If both grains of corn or both bean seeds germinate in one pot, remove the last one to germinate or the weaker one.

You may assume for purposes of this laboratory experience that all of the grains of corn possess essentially the same hereditary make-up. You may make a similar assumption for all of the bean seeds. Any differences, therefore, which appear in the growing plants may be assumed to be due to environment.

Place all six flower pots in a well-lighted area (natural daylight if possible, but not necessarily direct sunlight). Keep the plants at room temperature. Water them regularly. Keep the soil moist but not wet. Many small waterings are better for plants than a few large ones.

How long does it take the seeds to germinate and grow to a point where they break through the soil? Do the corn grains or the bean seeds develop first? Do all the seeds of each kind break through at the same time?

Take this opportunity to examine the internal structure of a corn grain and a bean seed. (If you soak them in water for 24 hours, they are easier to dissect.) What structures are alike in the two? What structures are different? Why? Examine a longitudinal section of each seed with a low power dissecting microscope or a hand lens. Distinguish the different parts. Look up the names and functions of these seed parts in a biology or botany textbook.

Measure the greatest height (from soil to the tip of the longest leaf, held upright for measurement) of each of the six plants at the same time each day. Record the measurements of each plant on a sheet of graph paper. You may want to try to put the records of all three corn plants on one sheet, and the records of all three bean plants on another. If you can do this, it will be easier to compare the growth rates of each kind of plant in the three different environments.

Measure and record data on all six plants for four weeks after they break through the soil. What are the results at the end of this period? How much difference has environment made?

Which is the more important in this case, heredity or environment? (Remember that heredity is assumed to be the same in this case for all three plants of each kind) Could either heredity or environment have determined the growth of the plant without the other? Is the relative importance of heredity and environment the same in the case of the bean plants and the corn plants? Do you think it is the same for all characteristics of each kind of organism, or are some characteristics influenced more by heredity and others more by environment?

Follow-Up:

Carry on the experience for a longer period if you can do so. Does the effect of environment increase with a longer time span? Decrease? Remain about the same? Why? Try the same experience with other kinds of plants. Are the results comparable? If the results are different, why do you think this might be so?

LABORATORY EXPERIENCE E.5.b.

Plants and Light

Introduction:

Green plants contain the green pigment chlorophyll. This pigment is able to capture the energy of sunlight and utilize it to combine carbon dioxide and water into simple sugars (carbohydrates). These are energy-containing compounds which can be used by the plant either for making other necessary substances (fats, proteins, nucleic acids) or as a source of stored energy for carrying on the activities that take place in the plant's cells. The process of using the energy of sunlight, with the help of chlorophyll, to make food substances is called photosynthesis.

All animals (including man) and colorless plants, (mushrooms, yeasts, molds and most bacteria) need the food materials which are made by green plants. We need carbohydrates, proteins, and fats as foods. We get them directly or indirectly from green plants. Life on earth depends on photosynthesis.

Some strains of green plants have green and white (mosaic) patterns on their leaves. The colorless areas appear white because they lack chlorophyll. Some plants may carry a hereditary factor for total absence of chlorophyll. This condition of course, is not survivable in nature unless the plant lives as a parasite on another plant. A few species do this. Free-living plants which show this characteristic die as soon as the food material in the seed is used up. However, the factor for absence of chlorophyll (albino gene) is carried as a recessive in some apparently normal plants, and is therefore able to persist by being carried along with a factor for normal chlorophyll. Green and white patterns also depend on a kind of heredity, but these plants have enough chlorophyll in their leaves to survive.

Green plants generally have other pigments in addition to chlorophyll. These include yellows, reds, and purples. In the fall in temperate climates, the green pigment breaks up first, and the other colors are left. This is why some trees and shrubs develop "autumn coloration" in their leaves before they are shed. In some plants these yellow, red and purple pigments are present to a sufficient extent that they show through the green at all seasons. Thus, we have potted plants and even trees and shrubs in which yellow, red, and purple coloration is mixed with green throughout the season. These are used for ornamental purposes. Their colors are also determined by hereditary factors.

In this laboratory experience you will be able to observe the operation of hereditary color factors in plants grown in different amounts of light.

Materials and Equipment:

Twelve flower pots, 6" in diameter

Albino corn grains (These can be obtained from General Biological Supply House, Inc., 8200 South Hoyne Avenue, Chicago, Ill., or any other biological supply company).

Normal corn grains

Rooted cuttings from Coleus plants showing as many colors as possible (These can be obtained locally from any greenhouse. Coleus is a common potted house plant. It is often called simply "foliage plant.")

Ruler

Collecting Data:

Before filling the flower pots as directed below, place a small stone or a piece from a broken flower pot over the hole in the bottom of each pot. This will help with drainage. Then, fill each pot to within an inch of the top.

Fill the 12 pots with garden soil. In four of them plant three grains each of albino corn. In four of them plant three grains each of normal corn. In each of the remaining four, plant one rooted cutting of Coleus. Take the cuttings from a plant showing as many and as bright colors as possible. Take all four cuttings from the same plant. Why? (Cuttings will normally root in ten days to two weeks if placed in water.)

Place one pot of each kind of planting in each of the following four environments with respect to light:

Direct sunlight (as of south window)
Indirect sunlight (as of north window)
Partial light (near center of classroom)
Total darkness

Keep the soil moist but not wet. Be sure that all pots are subjected to the same conditions of temperature.

Observe all of the pots daily. Record any data which appear to be significant.

How long does it take the corn seedlings to break through the soil? Is there any difference in this respect between the albino corn and the normal corn? Is there any difference in either type of corn between pots exposed to different conditions of light?

What about the rate of growth of the corn seedlings (both types) in different conditions of light?

Is there any difference in the development of green pigment in the normal corn under different conditions of light? Why or why not?

How long does the albino corn live? Is there any difference in the time of its survival under different conditions of light? Why or why not?

The ability to develop green pigment or the lack of it is a part of the heredity of the corn plants. What is the role of environment in this case?

Is it possible for the heredity of the corn plant to produce green pigment without working with the environment? Why or why not? Is it possible for the environment of the corn plant to produce green pigment without working with heredity? Why or why not? Is it possible to determine, in the case of the development of green pigment in the corn plant, which is the more important, heredity or environment. Which do you think is the more important? Why?

Is there any difference in the rate of growth of the *Coleus* plants under different conditions of light?

Does the amount of light have any effect on the development of pigments in the *Coleus* plants? Is there any difference in the effect of the amount of light on the different pigments, or are all pigments affected in the same way and to the same extent?

Make hypotheses to explain any differences that you have been able to observe in the *Coleus* plants grown under different conditions of light, or the lack of differences. Do this in terms of the interaction of heredity and environment. Which do you think is the more important in this case? Could either have functioned without the other?

Follow-Up:

Try the effects of other environmental factors on the *Coleus* plants. Does fertilizer have anything to do with the development of pigments? How about temperature?

Secure a specimen of a plant having leaves showing green and white patterns. Try growing cuttings from this plant under different conditions of light. Does amount of light have any effect on its growth? Try other environmental factors. Do the white areas differ in size under the influence of different environmental factors? Do you think it might be possible to set up an environment sufficiently favorable that the white areas would disappear altogether? What is the method by which the green and white pattern of leaves is inherited?

LABORATORY EXPERIENCE E.5.c.

Human Characteristics: Heredity or Environment?

Introduction:

There are some human characteristics which are readily recognized as having a hereditary basis: eye color, curly hair, facial features, height, and body build, for example. Others, such as suseptibility to disease, are less widely accepted as being related to heredity. Still others, including personality traits, general mental ability, and various special abilities (such as music, art, mechanics and mathematics) are thought by many people to be due mostly, if not entirely, to environment.

In this laboratory experience we will examine a physical trait, and ask ourselves if environment could in any way influence its expression. Then, we will examine a trait of behavior and ask ourselves if it could have a hereditary basis.

Materials and Equipment:

No materials or equipment are necessary for the first part of this laboratory experience. For the second part the following are necessary:

Filing cards, 3" x 5"

Tags

Scissors

Envelopes

Ruler

Collecting Data:

The inheritance of eye color in humans is ordinarily presented as being based on two kinds of hereditary determiners or genes: brown and blue. There is a single pair of these. The pair may consist of two brown genes, two blue genes, or one brown gene and one blue gene. The brown gene is stronger than the blue, and is dominant over it when the two are present together. Therefore, two browns, or a brown and a blue, will produce brown, while only two blues together will produce blue. There is no question that this pair of genes exists. And there is no question that it is the principal basis for determining eye colors. But is this the whole story?

The color of eyes in humans is due principally to the amount of one pigment, melanin, which is present. This is a dark pigment, which is also found in hair and skin. Albinos, who have a gene for total absence of color in skin, hair and eyes, never develop any dark pigment in their eyes. Their eyes are pink, because of the blood vessels that show through. Have you ever seen pink-eyed white rabbits? Background coloration may result in a very light blue in the eyes of human albinos.

In all other people some melanin is deposited. The depositing of melanin takes place in the iris of the eye. It begins at a particular point of time in the development of the embryo, and it ends at a point which differs in individuals. Darker eyed persons are those in whom the depositing of melanin goes on faster and/or for a longer time. Heredity factors serve to determine the rate and timing of the process of pigment deposition. Sometimes the process is completed before birth or shortly afterward. These people remain blue-eyed. Sometimes it continues into childhood, or even into adulthood. These people become hazel-eyed or light brown-eyed or dark brown eyed.

Observe closely the colors of the eyes of all members of your class. Is it possible to classify all of them as either "brown" or "blue?" Try to put them into the smallest number of color groups that is possible. How many color groups are necessary? Try out your color groups by attempting to classify the same number of persons outside your class. Do you find any individuals who do not fit into any of the groups? If you do, you will need to revise your classification, and possibly create a new color group. Continue to try out and revise your classification until you are sure that you can use it to classify any person whom you might meet.

Now line up the members of your class in such a way that they form an eye-color gradient, from the person with the darkest eyes to the person with the lightest eyes. Can you draw a line between "brown" and "blue" on the gradient? Where does "brown" stop and "blue" begin? Is there a gradient within the brown range, and within the blue range (some darker and some lighter)? What about the color groups which you have identified between brown and blue?

Do you think that a single pair of brown-blue genes is sufficient to account for human eye color? Would it be possible with a single brown-blue pair to have colors other than one shade of brown and one shade of blue? One possible explanation of the other color groups would be the existence of modifying genes (intensifying genes and diluting genes). Another would be the influence of the environment, modifying the action of a single pair of genes. Which do you think is the most likely explanation? Why?

The second part of the experience has to do with the development of a simple skill. Students will each get a puzzle made from a 3" x 5" filing card from the teacher. They will also each draw a tag with a number. The tags will be numbered, beginning with (1), to correspond to the number of students in the class.

Students will contest in pairs. As many pairs may contest at a time as there are umpires to watch them. Students who are not contesting at a particular time may serve as umpires. In each contest the student who gets the puzzle together first is the winner.

Each student will contest three times in each series of trials. For the first trial, the pairs numbered (1) and (2), (3) and (4), (5) and (6), (7) and (8), and following, will contest. For the second trial numbers (1) and (3), (2) and (4), (5) and (7), (6) and (8), and following will contest. For the third trial, numbers (1) and (4), (2) and (3), (5) and (8), (6) and (7), and following will contest. Students losing all three of the contests will retire from the game.

The numbers should be collected at this point. The remaining students who are still in the game will draw new numbers in a series beginning with (1). They will repeat the process, each contesting three times in the same numerical order as before, using the same puzzle. Again the three-time losers will retire from the game.

Additional contests following the same pattern will continue until all students except one have been eliminated. This remaining student will be declared the winner. If more than one class group has been engaged in the same laboratory experience, the "champion" of one class group may contest with the "champion" of another. This may be done if the same puzzle has been used in both classes. If different puzzles have been used, the situation would not be comparable. Why not?

How is this laboratory experience like competition in business or politics? How is it different? Is success in these fields based in part on inherited ability? Or is it entirely a matter of hard work? Or luck? If a part of it is based on good home background, how much of this, in turn, is due to inherited ability in the family line?

How much do you think inherited ability had to do with winning this contest? How much do you think environment had to do with it? What kind of hereditary factors, if any, could have been operating? How do you think environment could have operated to contribute to the result? Which do you think was most important, heredity or environment? Why?

Follow-Up:

What about other human traits? What about susceptibility or resistance to respiratory disease? Heart disease? Cancer? Mental disorders? What about personality traits? What about high temper? Moodiness? Criminal tendencies? What about special abilities? What about musical ability? Artistic ability? Mechanical ability? Mathematical ability? Ability to learn languages easily?

To what extent do these traits have a hereditary basis? To what extent are they due to environment? Is it possible for any traits of this type to develop without some interaction of both heredity and environment? Does the relative importance of heredity and environment always have to be the same in the case of different traits?

E.6. Idea That Rates and Changes Are Necessarily Related

Idea Bridge: Changes That Depend on Rates

A city tends to grow most rapidly through the development of residential or "bedroom" suburbs on the windward side. This is the side from which the prevailing wind blows. The city grows in other directions but more slowly. Soon the building of new schools, new streets and highways, new sewers and new water lines changes the geographic balance of the area. The increased sale of new household products, labor saving devices, lawnmowers and landscaping materials changes the economic balance of the area. The map shows a large bulge of urban development on the windward side.

A business enterprise finds that one particular line of its products is growing rapidly in popularity and sales volume. Other lines are increasing less rapidly or are remaining the same. Soon the major effort of the company is turned to the popular line, and the entire shape of the company is changed.

You find that you do very well in science and mathematics and less well in English and history. You will probably take all the science and math courses you can, and only as much English and history as you have to take. If you go to college you will probably major in science and mathematics, and go into scientific research or teaching, or into medicine or some other applied science. The whole future shape of your life will be determined by the area in which you "grow" most readily.

These are all examples of differential rates of increase. Such differential rates also affect the relative numbers of different species in plant-animal communities. Sometimes, but rarely, a species becomes extinct quickly because of starvation or disease. More often, a species becomes extinct very slowly because it does not reproduce as rapidly as its competitors. Any increase or decrease in the numbers of a species affects the shape of the community.

The changes in the surface and the outlines of the continents is the result of the differential rates of rising of some areas, sinking of other areas, the erosion of materials from high areas, and the deposition of these materials in lower areas. The different rates of these processes cause differences in the shape of the continents.

Differential rates of growth play a major part in the development of animal embryos and plant bodies. The arms, legs, head, general shape of the body, and most internal organs of animals are formed because of differences in the rate of growth of cells in certain areas. Leaves, branches, flowers, and various other special structures in plants are formed in the same way. Many internal processes, such as the depositing of color pigments in skin, hair, and eyes are dependent on differential rates. Some differential rates continue all your life. Compare the appearance of an old person and the appearance of a young person of the same sex. The differences are the result of differential rates of processes that have operated slowly through the years.

LABORATORY EXPERIENCE E.6.a.

Development of a Chick Embryo

Introduction:

The chick is standard material for the study of embryonic development in a vertebrate (backboned animal). The early stages of all vertebrate embryos (including human) are much alike, and the chick embryo is easy to work with and observe. Besides, its incubation period is short (three weeks). By starting a series of eggs incubating at the same time, and opening one each day, it is possible to see the progressive development of body form. This is particularly interesting during the first four or five days of development. During this period the basic body form is attained, and the principal organ systems begin to take shape. After this, the rest of embryonic development is largely a matter of growth in size, and changes in the relative proportions of different body parts.

The shaping of the embryo, both outside and inside, takes place because the cells in a particular area multiply faster and/or for a longer time than the cells in surrounding areas. Therefore, the rapidly growing cells "pile up."

Cell growth generally takes place in layers. When cells in a layer grow faster or longer at one point than at surrounding points, the resulting cell accumulation may take the form of a pocket inward, a pocket outward, a fold, a thickening, or a migration of the newly formed cells into other areas. These five processes result in the formation of noses, eyes, ears, arms and legs, fingers and toes, the shape of the head, the shape of the body, and other shaping of the outside form of the embryo. Internally, the same kind of growth results in the formation of liver, lungs, stomach, pancreas, kidneys, reproductive organs, brain, the internal parts of the sense organs, heart, blood vessels and blood, and other structures.

Other processes of development depend on the formation of particular chemical compounds, such as the pigment melanin that darkens hair, eyes and skin. Here the rate at which the pigment is formed and the length of time during which it is formed determine how dark the hair, eyes, and skin become. The dark-complexioned, dark brown-eyed person, with dark brown or black hair is one in whom the formation of melanin proceeded faster and/or for a longer time than in the person with light brown or blue eyes, light brown or blond hair, and fair skin.

The results of the operation of differential growth rates can be seen readily in the developing chick embryo during the first few days of incubation.

Materials and Equipment:

Incubator that can maintain a temperature of 103 degrees Fahrenheit

Fertile chicken eggs (These can usually be obtained from a hatchery)

Low power, wide field dissecting microscope (A hand lens may be used, but it is less satisfactory)

Syracuse watch glasses or other small shallow dishes

Dissecting scissors with sharp points

Prepared slides (whole mounts) of 24 hour, 48 hour, 72 hour, 96 hour, and 120 hour chick embryos (Although the experience can be carried on without these, they add greatly to it)

A textbook of biology or embryology containing labeled pictures or diagrams of chick embryo whole mounts: 24 hour, 48 hour, 72 hour, 96 hour and 120 hour.

Collecting Data:

Place fertile chicken eggs in an incubator (Temperature 103 degrees Fahrenheit). Start a minimum of 15 eggs. This will include three eggs each for the 24 hour, 48 hour, 72 hour, 96 hour, and 120 hour stages. Starting three eggs for each of the stages you wish to observe allows a margin of safety for infertility and mistakes in technique. (Remember that although we speak of "stages", the development of the embryo is really a continuous process.)

Open at least one egg at the same time each day for five days. These eggs will represent the developmental stages indicated above. To open an egg, do the following:

a. Place the egg in a Syracuse watch glass, or other small shallow dish. Ordinarily, in the early stages, the embryo floats on top when the egg is laid on its side.

b. Bore a small hole through the egg shell with the sharp point of a pair of laboratory scissors. The hole should be about three-fourths inch to one side of center as the egg lies.

c. Then cut a small circular window with the scissors, about one and a half inches across, through the shell on the side of the egg lying uppermost. Start with the hole you bored, and cut around the circle.

d. The oval piece of egg shell that is removed may be placed in the watch glass at the side of the egg, to wedge it and hold it steady for observation.

Observe the freshly-opened embryo with the unaided eye, and with a hand lens or a low power dissecting microscope. It is interesting to note that in observing living chick embryos with the unaided eye, you are following in the footsteps of all of the early embryologists from Aristotle (in the 400's B.C.) to William Harvey (in the 1600's A.D.) They likewise incubated eggs and opened one each day to observe its development.

Compare the living embryos at each incubation stage with stained, mounted specimens of the same stage. Look up the names of the structures that you see in a biology or embryology textbook. Observe as many of the structures as you can.

Note particularly those structures which can be seen in the stained specimens and that are visible in the living embryos also. You can see some things in the stained specimens at an earlier stage than you can see them in the living embryos. Why do you think this may be?

What is the earliest structure that is visible in the living embryo? At what stage can you see it? Did you see it earlier in the stained specimen?

When does the beating heart first appear? At what stage can you see the heart structure in the stained embryo? Look up the stages in the development of the heart in a *biology* or *embryology* textbook. Is it possible to explain the development of the heart in terms of differential growth rates?

Note the progressive development of body structures along the *embryonic axis* (the head-to-tail axis of the body). Which end of the axis develops most rapidly? Note the appearance of brain and sense organs. At what stage do they appear? Compare the living and stained specimens in this regard. Read about the development of nervous system, brain, and sense organs in a *biology* or *embryology* text. Is it possible to explain what you have seen and read in terms of differential growth rates?

Note the development of *wing buds* and *limb buds*. Again compare stained and living specimens. Is it possible to explain this development in terms of differential growth rates?

Note the twisting of the body to one side, beginning at the head end. At what stage does this begin? In what position is the embryo lying on the yolk in the early stages? In the later stages? Why do you think this takes place? How does it take place? Is it possible to explain how it takes place in terms of differential growth rates?

Note the growth of the yolk sac outward over the yolk. Read about the development of the yolk sac and other extra-embryonic membranes in a *biology* or *embryology* text. What is the function of the yolk sac? Of the other extra-embryonic membranes? Explain in terms of differential growth rates.

Read in a *biology* or *embryology* text about the development of liver, lungs, pancreas, and other internal organs. How are the blood vessels and blood formed? What is the role of differential growth rates in the formation of internal organs?

Identify in your study of the development of the embryo, the occurrence of *inpocketing*, *outpocketing*, *folding*, *thickening*, and *cell migration.* Which of these processes took place in the formation of each of the structures that you have observed or studied about?

Follow-Up:

Follow the development of the chick through to hatching by opening eggs at later stages of incubation. Hatching usually takes place on the twenty-first day. Note in particular, the growth in size and changes in body proportions that take place after the fifth day. Can you account for these in terms of differential growth rates?

Study the stages in the development of a human embryo in a book on human embryology. If a collection of preserved human embryos is available in a museum to which you have access, observe these. Compare them with the developmental stages of the chick during the first five days. On the basis of the length of time that it takes a human embryo to develop (10 lunar months of 28 days each), what ages of the human embryo would correspond to the five stages of the chick that you have studied? Compare them at these points.

LABORATORY EXPERIENCE E.6.b.

Development of a Bean Plant

Introduction:

The same basic growth processes take place in both plants and animals. Cells divide by the process of mitosis, involving an equal distribution of the materials of heredity from a mother cell to two daughter cells. Cells, however, do not always divide at the same rate. The growth rates of various portions of the body of a many-celled plant or animal are under the control of chemical substances called enzymes and hormones. These are produced by the cells themselves or by special structures. The production of these substances is, in turn, under the control of hereditary factors.

As a result of the operation of differential growth rates, where one portion of the body of a plant or animal grows faster and/or for a longer time than the surrounding parts, the body form is shaped by these growth processes. Branches, leaves, and flowers on a plant, or arms, legs, and head on an animal take form.

In this laboratory experience you will have an opportunity to observe the growth of a common plant from this point of view. You have seen plants grow all your life, but you have probably never thought about their growth in this way.

Materials and Equipment:

Flower pots, 6" in diameter

Garden soil

Bean seeds

Ruler

Graph paper

Biology or botany textbook.

Felt point marking pen

Collecting Data:

Plant one bean in each of five six-inch flower pots, filled to within one inch of the top with garden soil. Note: Before filling the pots with soil, place a small stone or piece of broken pot over the hole in the bottom of each pot to help with drainage.

Place the pots in a warm location in good light. Water regularly. Keep the soil moist but not wet. How long does it take the bean seedlings to break through the soil? Do all five break through at the same time? Keep a record.

How does the break through take place? Can you describe the behavior and growth of the seedlings in terms of differential rates?

What are cotyledons? Look them up in a biology or botany textbook. Is their unfolding a matter of growth through cell division, or some other process? What is the first structure to develop after the unfolding of the cotyledons? Can you describe its development in terms of differential growth rates?

Measure the developing leaves at the same time each day with a ruler. Record measurements to the nearest millimeter or fraction of an inch. Measure the leaves from the time of the earliest appearance of the leaf until growth ceases. Measure both length and width of each leaf. Keep a record on graph paper of the successive measurements of each leaf. Measure and record measurements of a large enough number of leaves to answer the following questions:

Do all leaves grow at the same rate?
Is the rate of growth in length and width of a leaf the same?
Do the proportions of different parts of the leaf change from the time of its appearance until its growth is complete?
Does it take all leaves the same length of time to reach their final size?
Is the final size which is attained by all leaves the same?

Set up a hypothesis to explain any differences that you find in the growth of different leaves, and different parts of the same leaf, in terms of differential growth rates.

Measure the height of each of the five plants every day (from the soil to the tip of the uppermost leaf, held upright). Record the measurement of each plant on a sheet of graph paper. Are there differences in the overall growth of the five plants? Set up hypotheses to explain your observations.

Seven days after the plants break through the soil measure the height of the bean plant which is growing most rapidly. Carefully mark with a felt point marking pen the stem of the plant at intervals of 1 centimeter or quarter inch. Measure and mark the plant every five days. Do the marks all remain 1 centimeter or quarter inch apart, or does growth alter the distance between them? Does growth occur at the same rate over the entire length of the stem?

Do some parts grow while others do not? Can you find a point of most rapid growth on your plant? Where is it? Set up a hypothesis to explain your observations. According to your hypothesis, would initials carved on a tree get farther from the ground as the tree grows taller?

Measure two branches on each plant, and keep a record of the growth of each branch each day. Measure from the main plant stem to the tip of the outermost leaf. Is there a difference in the rate at which branches grow? On the same plant? On different plants?

Can you describe the development of the bean plant in terms of differential growth rates? How is the general shape of the plant determined by differential growth rates? How are the different parts of the plant describable in terms of differential growth rates?

Follow-Up:

Carry on the same laboratory experience using a tomato plant grown from a seed. Observe a climbing plant, such as a gourd vine or a grape vine. These plants have twisted tendrils that hold onto the object of attachment. Study the tendrils closely and watch their development. Explain their development in terms of differential growth rates.

LABORATORY EXPERIENCE E.6.c.

Differential Growth Rates in Humans

Introduction:

We know individual humans better than we know individuals among other kinds of animals. This is partly because man is more variable than most other species of animals. Therefore, we are very conscious of the physical differences that distinguish humans from one another. These include body size and shape, skin color or complexion, eye color, hair color, shape of face, size and shape of nose, and other differences.

These characteristics develop as a result of the operation of differential rates of growth and differential rates of processes during embryonic life. The cells in one area of a developing individual grow faster and/or for a longer time than the cells in surrounding areas. Because of differential growth, the relationships of height and breadth of the body differ in different individuals. Arms and legs are formed, and fingers and toes on the ends of them. Chemical substances such as melanin (the pigment which causes dark color in eyes, hair and skin) are produced more rapidly and/or for a longer time in one individual than in another. As a result of all of these differential rates operating over the period of development, the form and appearance of individual humans is shaped, and various distinguishing characteristics are formed.

In this laboratory experience you will have an opportunity to observe some simple examples of differential growth rates and their results in humans.

Materials and Equipment:

Graph paper

Plain paper

Millimeter rule (a ruler marked in fractions of inches will work, but not so well. Why?)

Filing cards, 3" x 5"

Collecting Data:

Measure the growth of your finger and toe nails over a period of time. Record the growth of the nail on each finger and toe on both hands and both feet on graph paper. Proceed as follows:

a. Trim each nail as short as possible for the start of the experience.
b. Measure the length of the nail from the cuticle at its base to its upper edge. Use a narrow strip cut from a 3" x 5" filing card. Mark the length of the nail as accurately as you can on the strip with a sharp pencil. Use a fresh strip for each measurement.
c. Measure the marked length on the strip of card with a millimeter rule. Record the measurement to the nearest full millimeter.
d. Measure the length of each nail once a week, on the same day each week.
e. Continue the experience for as many weeks as you can. The longer you do so, the more interesting your results will be.

Try to answer the following questions:

a. Do all of your nails grow at the same rate?
b. Do your toe nails grow at the same rate as your finger nails?
c. Do the nails on the right and left sides of your body (finger and toe) grow at the same rate?
d. Do all of the nails on any one hand or any one foot grow at the same rate?
e. Explain any differences you find in terms of differential growth rates.

Compare your results with those obtained by other members of the class. Are there differences between the growth rates of the nails of different individuals? Between boys and girls? Between children and adults?

Follow-Up:

Draw outline profiles of the noses of ten adult men or women. Try to find as many different nose shapes as possible. Do the same thing for the noses of ten children your own age. In which group do you find the greater differences? Why? In development, do all parts of the nose grow at the same time? Explain the differences in the shapes of noses that you have observed in terms of differential growth rates.

Look at your own face in full front view in a mirror. Are the two sides of your face alike? With a piece of stiff white paper, cover first the left side and then the right side of your face. Are there any differences between the two sides? Imagine each side extrapolated to make a complete face. Would you be "two people?" Which side of your face do you like better? Can you explain any differences between the two sides in terms of differential growth rates?

Observe other differences in a series of human subjects: shape of hands, length of fingers, shape of head, general body build. Can you explain these in terms of differential growth rates? Can you explain the differences in body proportions of men and women in terms of differential growth rates?

Consider the differences in body proportions between a goung adult person and an old person of the same sex. Can you explain what you observe in terms of differential growth rates.

LABORATORY EXPERIENCE E.6.d.

Developing Stream Patterns

Introduction:

There are many features on the earth's surface that are the result of differential rates of processes. Some streams run faster than others. Waves are higher on some shorelines than others. There are differences in the amount and rate of air movement. Hurricanes occur in some areas, and there are areas of doldrums. You can think of other natural phenomena that occur at differing rates.

In this experience we will investigate the differing rates of water flow, and what these cause.

Materials and Equipment:

Sand table, sand tray, or other large flat container

Sand

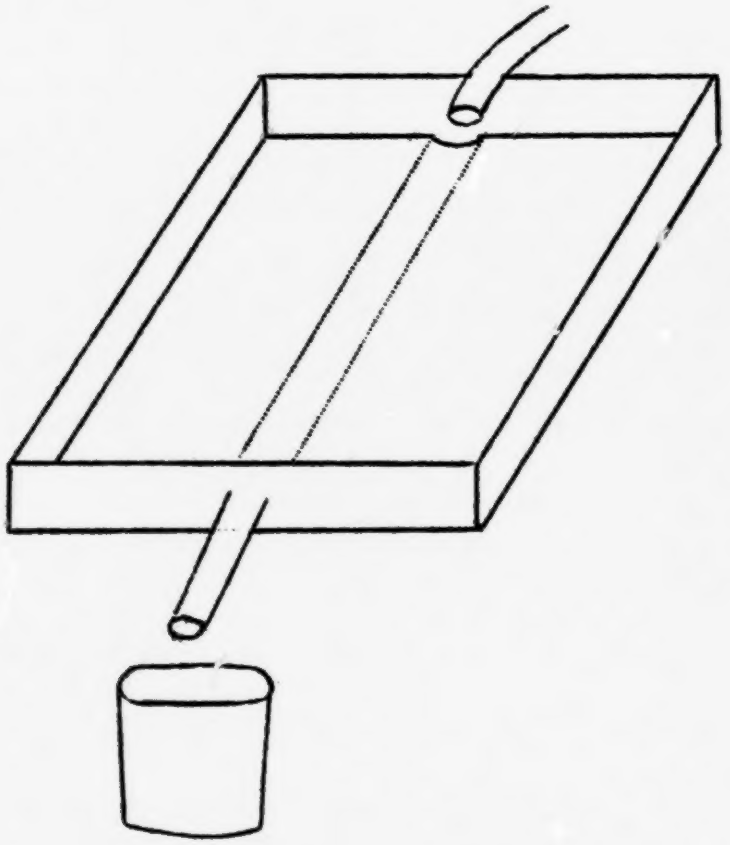
Clay

Running water

Pail or other drainage basin

Collecting Data:

What determines the velocity of a river? Use a sand table, sand tray, or a large plastic wading pool. Put clay in the bottom. Make a wide "valley" in the clay. Make a narrow straight channel in the valley.

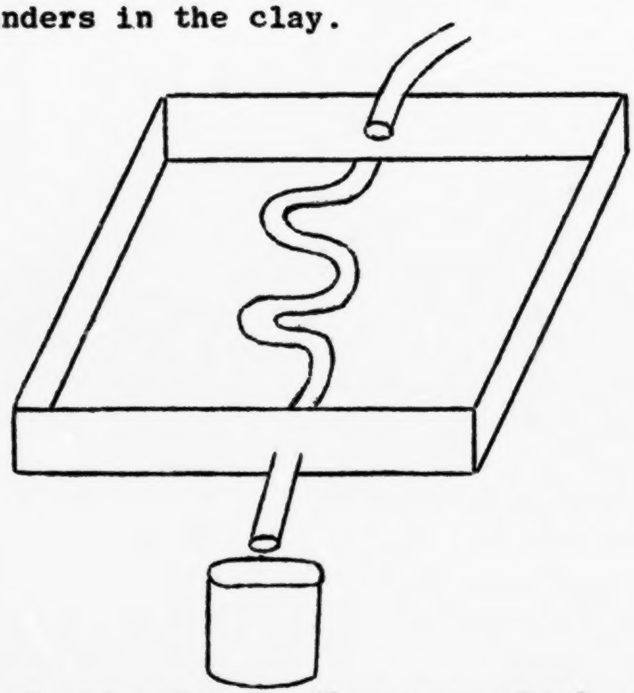


Raise one end of the table or tray about eight inches. Let a mixture of sand and water flow through the channel. Note the velocity of the stream. What happens to the sand in the water? What happens to the stream bed?

Now lower the end of the table or tray to four inches. What happens to the velocity of the stream? To the stream bed? Is there any deposition of sand? Lower the end of the table or tray until it is level. What happens to the velocity of the stream? To the stream bed? To the amount of deposition? Will the stream begin to meander?

Place a small stone in the "river bed," as if it had been dropped there when the stream was more nearly level. Now see if a meander will form? Why?

Now model several meanders in the clay.



Allow a mixture of sand and water to flow very slowly through the meandering stream. As the course of the "river" changes, which side of each curve is eroded, and on which side is sand deposited? Why is there erosion on one side and deposition on the other? Can you see any difference in the rate at which the water is moving in different places? Is there any relationship between rate of flow and erosion and deposition? Would it be easier to see this difference in a real river? Why?

What effect does this process of erosion and deposition have on the bed of the "river?" Try to show with your model the formation of a cut-off and finally of an oxbow lake through changes in the "river."

Follow-Up:

If you can find an opportunity to do so, observe differences in rate of flow and the relationship of these to erosion and deposition in a real river. One way to observe rate of flow in a river is to throw sticks in the water and observe their behavior. What evidence do you see that differences in rate of flow have resulted in the formation of meanders? How is it possible to reconstruct the history of a river valley, and tell something about its age, by observing the present-day form of the river?

What are other stream patterns that are made by erosion and deposition? What about deltas? Alluvial fans? Natural levees? Can you see any of these by observing dirt piles that are subject to erosion? What about gullies in eroded fields?

E.7. Idea That Man and His Tools Are Necessarily Related

Idea Bridge: We Sharpen a Word to Express An Area of Man's Relationships

We use the word "tool" to refer to things which man uses in his work: hammers, saws, jacks, scissors, crowbars, et cetera. We also use the word "tool" to refer to things like typewriters, draftmans' tools and microscopes. These are what we mean when we say that a secretary,a draftsman's,a laboratory technician, or any other kind of specialist "knows how to use the tools of his trade."

When we talk about the Idea of Tools, however, we are using the word "tool" in a much wider sense. A "tool" is anything that is used to solve a problem. It is anything physical, or social, or mental which man uses to meet the challenge of his environment. We have thus sharpened the word "tool" by giving it a special definition (see Laboratory Experience B.4.b. "Scientific Terminology")

Tools are extensions of man's body. They can function as extensions of arms and legs, extensions of communication organs and sense organs, and extensions of other human capabilities in solving problems of living. This concept includes simple tools like hammers and knives and forks, travel tools like automobiles, airplanes and boats, household tools like washing machines and dishwashers, communication tools like radios and telephones. Clothing and housing are tools that extend man's capabilities of living (or even surviving) in certain kinds of environments. Spoken and written language are tools that extend man's capabilities of communicating in both space and time. Once the Idea is accepted the list of examples is almost endless.

LABORATORY EXPERIENCE E.7.a.

Extending Man's Body With Tools

Introduction:

A laboratory experience is any situation where an answer to a problem is being looked for. Usually this involves a great deal of doing, and some thinking in connection with the doing. Here we have a different kind of laboratory experience; one that involves a great deal of thinking, and some doing in connecting with the thinking.

Man has many capabilities through the use of parts of his body. Anything which makes it possible for him to use his body more effectively, or to accomplish a wider range of activities, extends the capabilities of his body and serves as a tool.

Materials and Equipment:

Watch

Sheet of typing paper

Megaphone

Foot ruler

Collecting Data:

Think of yourself in comparison to a four-footed animal such as a cat or dog. Try to think of something that you can do that the cat or dog cannot do at all, not even to a small degree. Can you think of any such thing? Be careful, because you may fall into the error of thinking that the cat or dog cannot do something that you can, simply because it does not do this in the way that you do. For example, a cat or dog cannot talk, but it can communicate to a considerable degree, and talking is just your way of communication. What things can you do to a greater degree than the four-footed animal? What things to a lesser degree? What things about the same?

Do you think the cat or dog can hear better than you can? What evidence do you have that makes you think as you do? How far from your ear can you hear a watch tick? Is the distance the same for both of your ears. Now make a paper funnel from a sheet of typing paper. Place it in your ear and try again. Can you hear with the aid of the funnel to a greater distance than before? How much greater? How much has the paper funnel extended your hearing?

Use a megaphone to extend your speaking. How much can you extend it? How is the function of the megaphone similar to that of the paper funnel? Why?

Some four-footed animals have claws, and you do not, although your finger nails and toe nails correspond to the claws of the four-footed animal. What items would you add to the list of materials and equipment that would enable you to scratch like a cat? To dig like a dog? Would these items serve to extend your hands in a manner like that by which the paper funnel and the megaphone extended your hearing and speaking? How is the extension similar? How is it different?

Move a small object with the end of a foot ruler held in your hand. How is this extending? How is throwing a stone extending? Think of other things that you can do that are comparable?

How many ways can you extend your legs if you cannot reach the top shelf in the cupboard? Does a bridge extend your legs so you can cross a river without getting your feet wet? Is a car a means of extending your legs so you can travel 70 miles an hour instead of walking at 4 miles an hour?

Follow-Up:

Are all tools extensions of man's body? Can you think of any tools that are not? Can any animals other than man use tools? Is the use of tools a real difference between man and other animals? How is tool use related to the fact that man walks on his hind legs? How is man's tool use related to his large brain? What do we mean when we say that man has a problem solving brain? What part do tools play in man's problem solving?

Try to write a definition of man as separated from other animals, using the ideas included in this laboratory experience.

LABORATORY EXPERIENCE E.7.b.

Doing Work

Introduction:

A scientist's definition of work is different from yours. He would call playing baseball work, where you would call it play. You say that studying for a test is hard work. A scientist says that it is not work at all. To a scientist work consists of the relationship of force and distance to the resistance of an object.

To a scientist work is done whenever the motion of an object is changed. You throw a ball---The ball is in motion---Work is done. A ball is coming toward you---You catch it---Its motion is changed---Work is done. A ball is coming toward you---You hit it with a bat---Its direction of motion is changed---Work is done.

You pick up a book to study---Its motion is changed from stationary to moving to stationary again---Work is done. You hold the book steady and study for an hour---two hours---a longer period. Nothing moves but your eyes. The only work you are doing is this motion of your eyes---Studying is not work. At least not to a scientist.

How does a scientist determine how much work is done? Is it possible to decrease the amount of work being done?

Materials and Equipment:

Block of wood with a screw eye in the end

Strip of wood with a screw eye in the end

Small triangular block of wood

Balance

Spring scale

Book

String

Masking tape

Collecting Data:

Scientists use a formula (mathematical model) to determine the amount of work done:

$$\text{Resistance} \times \text{Distance} = \text{Work}$$

Weigh the block of wood containing the screw eye on a balance. You have now found its resistance. Raise it by attaching it to a spring scale. The scale records how much force you are using. Does the force equal the resistance? Can we then rewrite the formula for work?

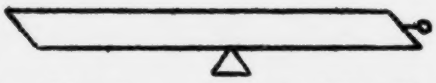
Force x Distance = Work

Weigh your book on the balance. Raise your book. (Measure the distance you raise your book in centimeters if your balance weighed in grams. Measure the distance in inches if your balance weighed in ounces). The unit of measure for work is gram/centimeters, ounce/inches, foot/pounds. How much work did you do in raising your book?

Attach a string to your book with a piece of marking tape. Drag the book along a flat surface attached to the spring scale. Is the force required the same as that needed to lift the book? Less? Greater? Why? What is friction? What does it do? Measure the distance you dragged the book. How much work did you do?

Place the flat piece of wood with the screw eye in the end on the small three-cornered block of wood.

This makes a simple machine called a lever. Raise the book you have been using with one end of the piece of wood. Pull down with the spring scale attached to the screw eye in the other end. Carefully measure the distance that the book moves (upward). Measure the distance that the other end of the stick moves (downward).



Compute the work you did in raising the book:

Resistance x Distance = Work

Compute the work you did by using the formula:

Force x Distance = Work

Is the result the same in the case of application of the two formulas? Why?

Follow-Up:

Did the lever actually make the work less? Or did it merely seem like less work? Why can you "teeter-totter" a child much heavier than yourself if you sit farther from the center. Think of other every-day examples of the use of levers.

LABORATORY EXPERIENCE E.7.c.

Extensions of Man's Body: Simple Machines

Introduction:

The complicated machines like automobiles and airplanes that we use in modern life are really combinations of simple machines that were discovered by primitive man early in his history. There are only a few of these simple machines.

This laboratory experience is designed to help you understand the physical relationships that are involved in these simple machines. Through these relationships these simple machines serve as extensions of man's body and its capabilities.

Materials and Equipment:

Yardstick (new, clean, and as free of knots and grain as possible)

Ring stand with crossbar or other means for suspending the yardstick and supporting an inclined plane

Triangular file

String

Set of weights up to 500 grams, or with combinations possible up to this amount

Spring type kitchen scales (two or more)

Laboratory balance

Board, 2" x 4", 8 feet long

A. The Lever

Collecting Data:

Make a notch across the top of a yardstick at its exact midpoint with a triangular file. The notch should be deep enough to hold a string which will be tied around the stick. Use a piece of string about six inches long. Tie it around the stick with the knot lying in the notch. Leave the two ends of the string of equal length. Tie the ends together, and hang the stick from a support. Does the stick balance? Or is one end higher than the other? If so, why?

Make shallow notches with the file across the top of the stick at each quarter-inch mark, from the midpoint to the end of each side. Be careful to make the notches straight across the top of the stick, as uniform in depth as possible, and each one exactly on the quarter-inch mark. Suspend the stick again. Is it as well balanced as before? If not, what do you think has happened?

Note: This is just like the yardstick you worked with in Laboratory Experience E.1.a. A Simple Balance. If you have this yardstick there is no need to make a new one.

Hang a 100 gram weight by means of a string from a point on one side of the stick. Then find the point where a 200 gram weight, hung in the same way, must be placed on the other side so that the stick will exactly balance.

The point where the stick is attached in the middle is called the fulcrum. If you multiply the weight on each side by its distance from the fulcrum you will get a figure which is called the moment of the force exerted by the weight. Find the moment of the force exerted by each of the two weights. What is the relationship between the two moments? Why?

Put a spring-type kitchen scale in the place of the 100 gram weight, and a 500 gram weight in the place of the 200 gram weight. Hold the scale in your hand and rest your elbow on the table in order to get a more accurate reading. Try various positions on the stick for both the weight and the scale. From the scale, determine the amount of force necessary to balance the 500 gram weight in each position. Replicate the experience with two or more spring-type scales, or compare your results with the results obtained by others who are doing the same thing. What is the margin of error that is involved? Keep this margin of error in mind when you are working with spring-type scales in connection with other laboratory experiences.

Your scale will probably be marked in ounces instead of grams. Look up the number of grams that are equal to an ounce. Use this gram equivalent for the number of ounces that you get. Calculate the moments in the case of all of the positions you have tested. Does the relationship between moments which you found above hold consistently? Is there a margin of error?

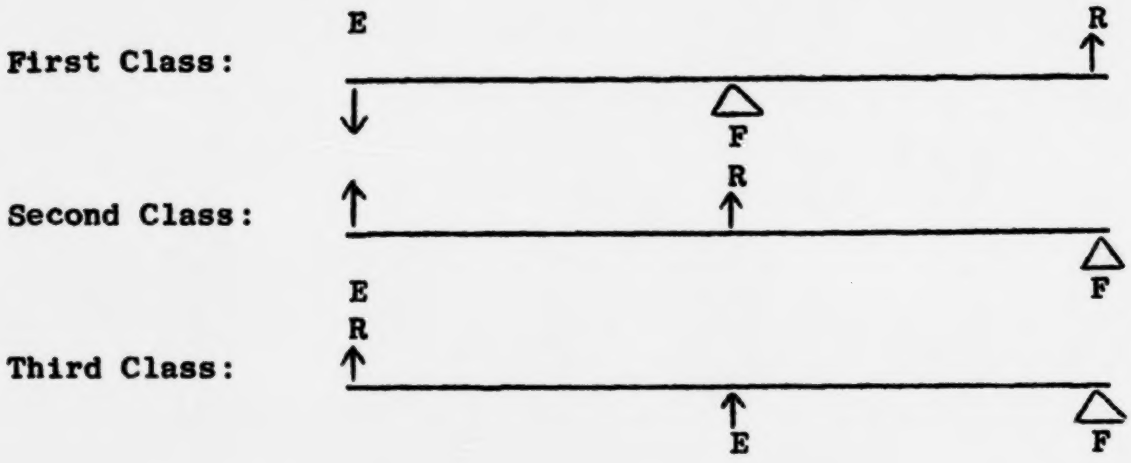
Put an object of unknown weight in place of the 500 gram weight. Assume that the relationships which you have found between moments holds consistently. Determine the amount of force exerted by the object of unknown weight. Weigh the object on a laboratory balance. Is the weight consistent with the force?

Use a 2" x 4" board eight feet long as a lever. Use a fulcrum resting on the floor. Raise objects of various weights. Determine the relationships in each case.

The lever is a simple machine. A small amount of force, exerted through a greater distance, is able to accomplish work in the form of moving a weight which exerts a greater amount of force through a lesser distance. A man, exerting only the force of his own body, using a lever, can move a much greater weight than he himself represents. An ancient Greed mathematician said that if he had a lever of sufficient length, and a fulcrum on which to rest it, he could move the earth. A lever, therefore, may be though of as an extension of man's body and its capabilities.

A lever consists of three parts. One is the place where the force (effort) is applied. The second is the fulcrum, the point on which the lever turns. The third is the place where the work is done (resistance). In a lever such as you have been using, the fulcrum lies between the effort and the resistance. This is called a lever of the first class. In a lever of the second class, the resistance is located between the effort and the fulcrum. In a lever of the third class, the effort is applied between the resistance and the fulcrum.

F = Fulcrum E = Effort R = Resistance



Follow-Up:

Set up examples of levers of the second and third classes, and see if the relationships which you have found for levers of the first class hold for these also. Think of common examples of tools that utilize levers of each of the three classes?

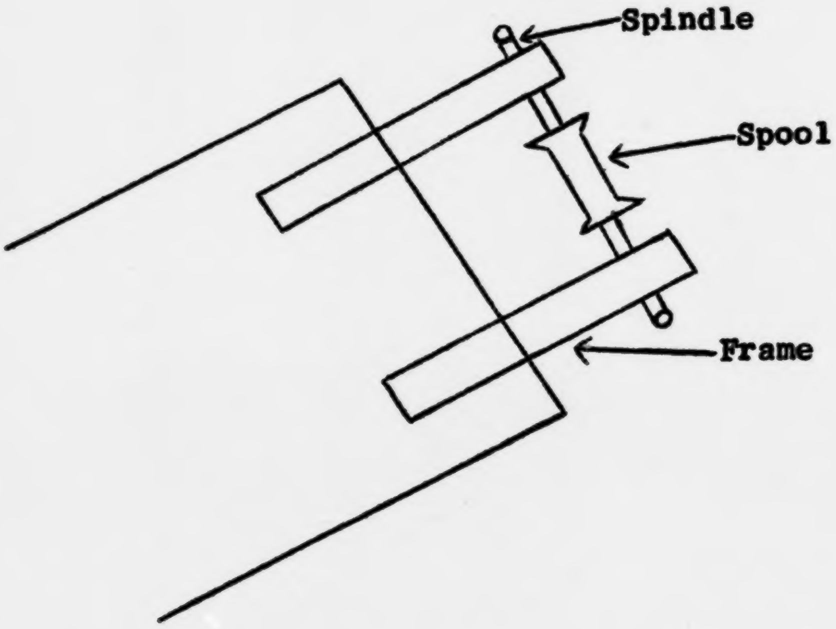
B. The Inclined Plane

Special Equipment:

Board, 1" x 6", 3 feet long, with a small pulley affixed at one end. The wheel of this pulley should be placed far enough beyond the end of the board so that when the board stands at a 45 degree angle a string can pass around the wheel and go straight down without touching the end of the board. (If a small metal pulley is not available, a pulley can be constructed by mounting a wooden spool on a spindle attached to a wooden frame. See below)

Protractor

Toy truck or other small wheeled toy, weighing at least 200 grams.



Collecting Data:

Set up an inclined plane at a 45 degree angle, using a 1" x 6" board, 3 feet long, with a small pulley attached at one end. Use a ringstand with a crossbar or other means to support the raised end of the inclined plane.

Thread a string over the pulley. Let both ends of the string hang straight down. Attach a toy truck or other small wheeled toy weighing at least 200 grams, to one end of the string, and a spring scale to the other end. Holding the scale in your hand, find the amount of force necessary to lift the toy, as shown by the reading on the scale. If the scale is marked in ounces instead of grams, calculate the gram equivalent of the number of ounces shown.

Weigh the toy on a laboratory balance. Does the weight of the toy correspond to the force which it exerts over the pulley.

Now detach the toy from the string, and re-attach it in such a way that the string over the pulley will draw the toy up the inclined plane.

Find the amount of force necessary to draw the toy up the inclined plane, set at a 45 degree angle. Use a protractor to measure the angle. How does the force exerted in this case compare with the force exerted when the toy was lifted straight up? What is the relationship? Multiply the length of the inclined plane by the amount of force necessary to draw the toy along it. Then multiply the height of the uppermost point of the inclined plane by the amount of force necessary to lift the toy straight up. What is the relationship between the figures obtained in the two cases?

Now adjust the inclined plane to an angle of 30 degrees. Determine the amount of force necessary to draw the toy up this less steep inclined plane. Compare the force exerted in this case to the force exerted in the case of the 45 degree inclined plane and in the case of the perpendicular pull. What is the relationship? Again multiply the length of the inclined plane by the amount of force necessary to draw the toy along it, and the height of the uppermost point of the inclined plane by the amount of force necessary to lift the toy straight up. What is the relationship between the figures obtained? Is the relationship the same as that found in the case of the 45 degree inclined plane? Why?

Change the inclined plane to an angle of 15 degrees and find the amount of force needed to draw the toy along it. Compare to the 30 degree inclined plane, the 45 degree inclined plane and the perpendicular pull. What is the relationship? Is it constant? Why? Again multiply the length of the inclined plane by the amount of force necessary to draw the toy along it, and the height of the uppermost point by the amount of force necessary to lift the toy straight up. What is the relationship between the figures obtained? Compare to the 30 degree inclined plane and the 45 degree inclined plane. What general conclusion can you draw?

In the case of the lever, you found that a small amount of force exerted through a greater distance is able to accomplish work in the form of moving a weight which exerts a greater amount of force through a lesser distance. Can you see a similar relationship here? Can you express what happens in both cases in the same general terms? Try to do so. What is meant by mechanical advantage? How may an inclined plane be thought of as an extension of man's body and its capabilities?

Follow-Up:

How are the wedge and the screw related to the inclined plane? Describe them in terms of the inclined plane. What common tools utilize the principle of the wedge? Of the screw? List as many examples as you can in the case of each.

C. The Wheel

Man's development of complex machines has depended largely on his discovery and use of the wheel. Is the wheel, considered alone, one of the simple machines. Why, or why not? What does the wheel do, considered alone?

Collecting Data:

Turn the wheeled toy which you have been using upside down, so that it drags rather than rolls, or use an object of identical weight and similar size, but without wheels.

Determine the amount of force, as measured by the spring scale, exerted in lifting the wheel-less toy or similar object straight up, with the string operating over the pulley at the top of the inclined plane. Compare this with the weight of the same object, weighed on the laboratory balance. Work out the gram equivalent of the reading on the spring scale as in previous experiences.

Now, using the spring scale, find the amount of force in grams necessary to drag the wheel-less toy or similar object up the inclined plane at a 45 degree angle. At a 30 degree angle. At a 15 degree angle. Compare the amount of force needed in each case with that needed in moving the wheeled toy in a comparable situation, obtained in your earlier experiences with the inclined plane.

What do you think accounts for the differences in the amount of force needed in moving the wheeled and wheel-less objects of the same weight up the inclined plane? Was there a difference in the amount of force needed in lifting the wheeled and wheel-less objects straight up? Considering this, what do you think was the function of the wheels?

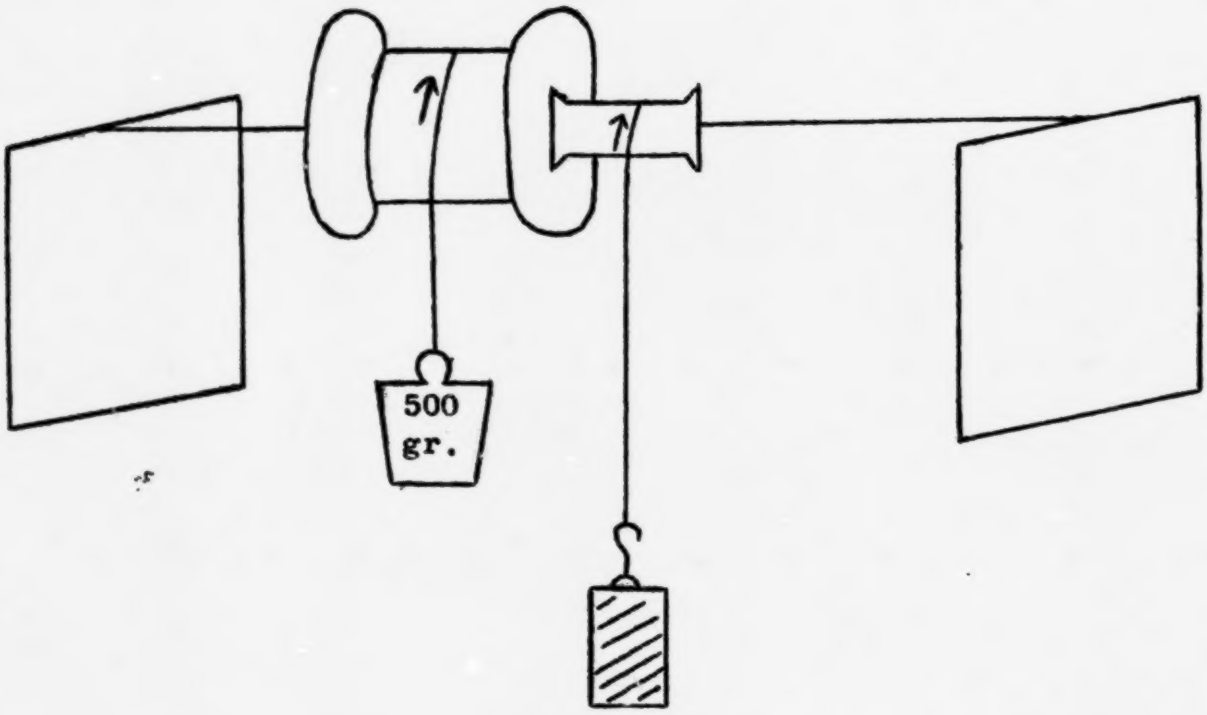
What is friction? What are some of the means that have been invented or discovered to reduce friction? Can it be eliminated altogether? Does it operate in connection with the movement of wind and water? With the rotation of the earth? With other kinds of motion in the universe?

A wheel and axle machine differs from the wheel you have been working with. The wheel you have been using turns on the axle. In a wheel and axle machine the wheel turns with the axle. The wheel and axle are securely fastened together. Examine a pencil sharpener. Try to turn the shaft without using the handle. The handle serves as the wheel. The shaft is the axle. Does the wheel make it easier to turn?

Examine a door knob. Take out the little screw that fastens the knob (wheel) to the axle. Try to open the door by using only the axle. Is it more or less difficult without the wheel? Why? Does the knob really do any work? Or does it merely make work easier? Notice how far you have to turn the knob in comparison to the distance the axle moves.

Special Equipment:

You can construct a wheel and axle machine by fastening a 12" wheel to a smaller wheel, such as a wooden spool, to serve as an axle. Or you can use a large spool and fasten a smaller spool to the end of it (see accompanying diagram). Run a small wooden dowel through the holes in both spools (or wheels) and lay it across a pair of supports. You will note that the dowel is not attached to the wheels, and therefore is not an axle. The wheels turn freely upon it.



Collecting Data:

Attach a string to the large wheel and hang a 500 gram weight on the end of it. Fasten a spring scale to the end of a string attached in the same way to the small wheel. How much effort is needed to raise the resistance? How far does the effort have to travel? How far does the resistance have to travel? Calculate the moment of force for each. How do they compare? How does this relate to similar results with the lever and the inclined plane? How is a wheel and axle an extension of man's body and its capabilities?

Follow-Up:

What about combinations of wheels? Gears? Pulleys? What about a fixed pulley such as you used at the top of your inclined plane? It operates on an axle but is not attached to it. What about movable pulleys, or combinations of fixed and movable pulleys?

Can you express what happens in the operation of gears and pulleys in the same general terms that you used to express what happens in the case of levers and inclined planes? Try to do so. How may gears and pulleys be thought of as extensions of man's body and its capabilities?

Is the wheel, considered alone, an extension of man's body and its capabilities? Is it a tool? What civilizations developed to a relatively advanced state without utilizing the wheel?

General Applications:

Bring in toys, household tools, and other devices that make use of the principles involved in these experiences. Note that some of these devices are based on simple machines, while others constitute combinations of simple machines. Cite examples of simple machines and combinations of them from work, sports, and life experiences in general. What about movements of the human body and the bodies of other vertebrates? What about the movements of insects? What about those of clams?

LABORATORY EXPERIENCE E.7.d.

Complex Machines and Utilization of Outside Energy

Introduction:

Man has learned to use energy from outside sources in addition to the energy of his own body. This outside energy makes possible the development and use of our complex machines. These machines multiply our productivity. These machines are so much a part of our world that we tend to take them for granted. However, they also are extensions of our bodies and their capabilities.

In this laboratory experience we will examine the relationship of man's complex machines (a) to the capabilities of his body, (b) to simple devices which have extended these capabilities, and (c) to outside sources of energy which make it possible for complex machines to extend these capabilities still further.

Materials and Equipment:

Square of stiff paper 5" x 5"

Ruler

Scissors

Pin

Lead pencil with rubber

Glass bead or small button

Cardboard fan

Electric fan

Some familiarity with a bicycle and an automobile

Can-and-string telephone

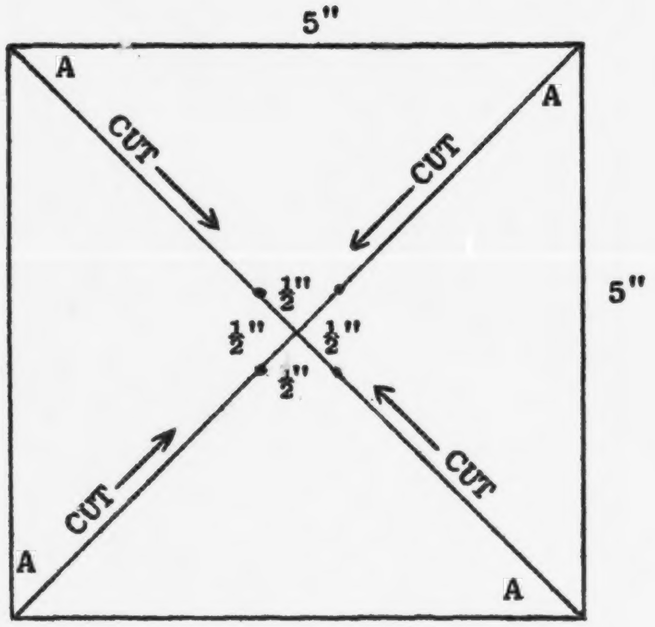
Some familiarity with telephone, radio and television

Collecting Data:

Construct a paper pinwheel:

Use a piece of stiff paper, exactly 5" square.
Draw two lines connecting opposite corners. If these are drawn carefully, the lines will cross in the exact center of the square.
On each of the four lines going out from the center, make a dot ½" from the center.
Cut in from the corners of the square along each of the four lines until you reach the dots.

Now bend in to the center each of the corners marked "A" in the diagram. Run a pin through the four corners and through the center of the square. Mount the pinwheel by inserting the pin into the rubber end of a lead pencil. Place a glass bead or small button between the pinwheel and the rubber to reduce friction.



Blow on the paper pinwheel. See how rapidly you can make it run by blowing on it. What proportion of the time are you able to keep it in motion? Try cooperating with someone else. Can you keep it in motion, or make it move faster, by working together?

Now use a stiff piece of cardboard as a fan to create currents of air. Are you able to make the pinwheel move faster, or keep it in motion more nearly constantly by using the cardboard fan as a simple tool? Try it with two people using cardboard fans. Can you work more efficiently, either alone or as a team, using a simple tool than by using only your breath? To what simple machine is the cardboard fan related?

Hold your pinwheel in front of an electric fan. Compare the rate and constancy of its turning with the results obtained by blowing on it, and by hand-fanning it. Can you arrive at any quantitative statement (based on a rough estimate) of the difference in behavior of the pinwheel under the three comparable conditions? Try to do so.

You have now retraced the development of human effort (using a simple example to illustrate a much broader and more complex process) covering a period of perhaps 20,000 years. This has involved the following stages:

a. Use of man's body and its capabilities
b. Use of a simple hand tool
c. Use of a complex mechanism, dependent on outside energy

See how far you can trace the source of the electrical energy that was used to turn your electric fan. What are some of the methods of producing electrical energy? Find out all you can about that happens when energy changes state. What is meant by conservation of energy?

Does all of the energy from the original source ever reach the electrically-operated device (for example, motor, light bulb, heating unit)? What happens to it along the way? How efficient is an electric motor? An electric light bulb? (That is, how much of the energy that actually reaches the device is turned into motion or light?) What happens to the rest of the energy?

Now go through a similar series of steps in your thinking, following a different line of mechanical development, using successively:

a. Locomotion by walking
b. Riding a bicycle
c. Driving an automobile

Note that in the case of the bicycle and the automobile you are dealing with complex machines which are combinations of simple machines. What are some of the simple machines that are involved? In the case of the bicycle, human muscle power is used as an energy source, the same as in walking. In the case of the automobile, an outside energy source is used.

Compare the degree of increase in accomplishment in this series with that which you have observed in the simple case of the pinwheel and the air currents. What is meant by "horsepower" in the case of an automobile or other type of engine?

How much of the potential energy of the gasoline is actually converted into motion by the automobile? What happens to the rest of it? Why does a small foreign car or a light American "compact" deliver more miles per gallon than a heavier car? What about accessories, such as power steering, power windows, power brakes and automatic transmission? How do these affect gasoline consumption? Why?

Now go through another series of steps. See how far away you can hear a watch tick. Then see how far away you can make yourself heard, speaking in a normal tone of voice. The use of the watch along with your voice gives you a standard of comparison for use in connection with the following experience.

Make a can-and-string telephone. Punch a small hole in the bottom of each of two large tin cans, the same size. Connect the cans with a long string attached through the holes. Draw the string as tight as you can.

See how far you can hear a watch tick through the can-and-string telephone. See how far you can make yourself heard through the can-and-string telephone, speaking normally. Try to arrive at a quantitative statement, comparing the distances at which the watch ticking and the normal speaking can be heard without and with the aid of the can-and-string telephone.

Now think of the vastly greater distances over which communication by voice is possible, using devices which depend on electrical energy in various forms: telephone, radio, television. When you do this you have followed a third series of mechanical devices, again retracing the development of human effort through the same three stages: (a) use of man's body and its capabilities, (b) use of a simple tool, (c) use of complex mechanisms powered by outside energy. Can you think of any other such series?

Follow-Up:

Think of other applications of outside energy that make possible man's adjustment to the modern world which he has created. What about space travel from the earth to the moon and planets? What forms of energy are involved in it? What forms of energy have been suggested for use in space travel over greater distances in the future?

What about new energy sources to replace those that are being used up? What about fission energy from radioactive materials? What uses are being made of it now, and what additional uses are in sight? What about fusion energy? What are the prospects for its development and control? What would development of a successful method of utilizing fusion energy do to the world's energy prospects?

LABORATORY EXPERIENCE E.7.e.

Extensions of Man's Body: How They Have Evolved

Introduction:

When man began to walk upright, he bagan an entirely new kind of evolution. Because his upright position left his hands free to grasp things, he began to use tools. He adjusted to his environment and tried to solve the problems that it presented by evolving tools, rather than by changing his body. This has been a kind of substitute evolution, or evolution by proxy.

Instead of changing himself into a highly specialized running animal like the horse, he invented and evolved machines to do his rapid traveling (automobiles, bicycles, and motorcycles.) In the same way, instead of evolving into a highly specialized swimming animal like a seal or walrus, he invented and evolved various kinds of boats and ships to do most of his swimming. He evolved weapons instead of specializing his teeth and claws for defending himself, fighting, and killing prey. He evolved airplanes to do his flying, bulldozers to do his digging, and even complex machines to do some of his remembering, calculating and thinking. The movement toward automation is a development of our time. Self-repairing machines may well be a development of the future.

There are many other examples of tools used to solve environmental problems. If it is raining you wear a rain coat to solve a problem of environmental adjustment. Your ancestors did not evolve a coating of coarse hairs to shed the rain as some other animals did. They invented clothing (including raincoats) instead.

You wish to get an idea across to another person. Getting it across constitutes a problem. You use written or spoken language as a tool to deal with this problem, possibly devising new word combinations or even inventing new words to adapt the tool to the need.

Social, political and economic systems are tools which we have evolved for dealing with problesm of commodities, media of exchange, distribution of goods, and standards of living. Money and commodities themselves are tools for meeting human needs. Ideas are tools for solving problems in human thinking. These ideas affect our actions.

The words that you have just read have been used in a particular combination as tools for expressing the idea that man has extended his physical body and its capabilities in many ways to adjust to his environment. The bodies of other animals have undergone structural changes in becoming specialized to deal with a particular kind of life. Later, because of their specialization, they have found themselves unable to live at all except in a special habitat: the sea, the freshwater of ponds and lakes, open plains, forests, the tropics, the arctic.

Man's body, on the other hand, has remained relatively unspecialized. By evolving and using tools, he has been able to adjust even better to the same problems to which other animals have adjusted. He has also adjusted to many other problems. It is because of this that man has become dominant over the whole earth, and soon, possibly, over other worlds also.

Resources for the Problem:

No special equipment or materials are necessary for this laboratory experience. A number of different kinds of resources, however, will prove useful. These include back files of magazines, especially the National Geographic Magazine. Nearly any library will have some of these. Sometimes complete or nearly complete files, going back fifty years or so, have been kept. Old newspapers, books on history, and books which describe or picture the ways in which people lived, and the things that they used before our time, will be helpful. We are living in a period of rapid change, and it will surprise you how shortly before our time conditions differed greatly from the present.

If a museum is available near where you are, it will furnish an excellent resource for study. Antique shops are full of things that people formerly used: old furniture, old dishes, old utensils, old tools, sometimes old books. Many people collect these things. Your parents or your friends' parents may have some of them. Old snapshots and collections of family portraits are useful in some cases. Conversation with older people, your grandparents or others their age, is a good resource.

A part of your problem is to locate the right kind of material. It is necessary to learn how to look for it. This is a good opportunity to learn about the community where you live, and the things and people in it. You should make the most of this opportunity. Any community has a great deal of material which will be useful for this study. A rural community is in some ways better than an urban community, and vice versa. The resources available in one are different from those in the other. No two communities, even of the same type, are alike in this respect. You will find your study very interesting.

Evolution of the Automobile:

The automobile began in the 1890's with a combination of some features taken from the bicycle and some from the carriage, together with an engine for propulsion. The engine was originally placed beneath the car, but was very quickly moved to the front, possibly because this was where the horse had been. There have been various experiments with rear-end drives. These have generally proven more successful in Europe than America. The German Volkswagen is a notable example. Can you think of any others?

The automobile has steadily evolved during the past two-thirds of a century toward a form that is uniquely its own, yet which still shows some evidence of its origin.

The National Geographic Magazine began publication in 1889. It has carried advertisements which pictured automobiles since the early years of this century. These advertisements constitute an excellent source for tracing the evolution of the external features of the automobile. Study these or any other available sources. What changes can you observe in the appearance of the automobile? Can you identify any trends? When did they first appear?

What kinds of cars were sold at the time of World War I that are no longer on the Market? Which of the present kinds were available then? What new ones have appeared? Were these really new or were they merely variant forms of older ones? How does the number of companies making cars now compare with the number at the time of World War I? What has happened? Why?

Of course the external appearance of cars tells little or nothing about internal changes. Talk with an older person who has driven cars for most of his life, and ask him to recall what some of these internal changes have been. How about number of cylinders? What about gear shift? What about the method of starting the engine? Any others? What about accessories? Is it possible to discover any trends?

Try to account for these changes in terms of the environment in which the automobile has operated in the past half century or longer (roads, growth of population, growth of cities, general improvement of standard of living). What about over-all size of cars? Compare automobiles American made cars with European imports in this regard. Try to account for any differences that you find. What about cost of gasoline? Has the quality of gasoline improved? Have cars become more efficient in their use of gasoline? What about tires? What about driving speed? What about cost of cars?

How has increased use of the automobile affected the geography of our cities? What about the future? What problems must we face in connection with increased use of the automobile? See if you can find out what are the present plans of automobile manufacturers with regard to new developments in engine and body design. What about fdderal and state government regulations?

Try to account for the changes which have occurred in the evolution of the automobile in terms of the survival of that which works, and elimination of that which works less well. This is called "natural selection." What are the selective factors that have operated in the evolution of the automobile?

Evolution of the Airplane:

The airplane began through experimentation with man-lifting kites and studies of the flight of birds. The first airplanes were essentially man-lifting kites with engines for propulsion. How does an airplane stay in the air? What is Bernoulli's Principle? Can you think of any common examples of the operation of the principle that you have observed?

With the attainment of greater speeds, the airplane has evolved steadily in the direction of becoming a projectile, manned or unmanned. How is this evident in its external appearance? What have changes in the kinds of engines used for propulsion had to do with this? What kinds of engines are now available for propulsion? The intercontinental ballistics missile (ICBM) and the development of space ships are the ultimate in this line of development. What means of propulsion and structural designs are possible for use outside the earth's atmosphere in interplanetary space? Why?

Study the evolution of the airplane following the same general lines of investigation that have been indicated for the evolution of the automobile. Here old magazines will give you less help. On the other hand, more material on present and possible future developments is available in current and recent newspapers, magazines, and books. Again talk with older people who remember some of the stages in the evolution of the airplane. What were biplanes? Have you ever seen an open cockpit airplane? How long have we had helicopters?

How have airports evolved along with airplanes? What about spaceports? Do we have any spaceports now? What effect has the military use of aircraft had on the evolution of the airplane? What about the increase in air travel by civilians? Has the use of the automobile also entered into this picture? What have been the selective factors that entered into the evolution of the airplane? Have they been the same as those that have operated in the case of the automobile? If so, why? If not, why?

Evolution of Language:

New words are constantly appearing. Sometimes they survive, but more often they do not. In some cases, however, whole new vocabularies replace old ones. When man's activities change, new words become necessary, and old words become obsolete. This happened when the automobile, truck and tractor replaced horses and horsedrawn equipment. The very words "truck" and "tractor" themselves were new or acquired new meanings. A "truck" formerly meant a small hand-pushed carrier for luggage. It is still used sometimes in this way. The word "tractor" is entirely new. What is the derivation of the word "automobile?" A generation ago radio, and more recently television, brought new words into the language.

Language evolution is related to people's need for expression in situations of actual living. When the situations and relationships change, language changes with them. At some periods and in some places, the change is rapid. At other times and in other places it occurs slowly or not at all. It is in this way, however, that the languages that we have in the world today have developed and differentiated from one another. Anthropologists estimate that it takes about 20,000 years for two languages which are descended from a common ancestor to become completely separated.

There are books on the development of language differences which are non-technical and interesting. Look for some of these in your local library. Occasional articles in newspapers can be found dealing with these topics. Your best resource, however, at least to begin your study, is your own experience. Observe differences in speech among people from different parts of the country, between rural people and city people, between older people and younger people. What differences can you discover? What is dialect? What dialects can you detect? Dialects differ in different sections of the country, sometimes even in different cities. Sometimes such differences can be detected on television, watch for them.

Talk to your parents and other older people, and with their help try to identify words like "radio," "television," "nylon," "paperback," that have come into existence in recent memory. You can easily compile long lists of these. Some you will be able to think of from your own experience. Others, like "refrigerator" are more than a generation old. Try to find out what brought them into existence. Some are manufactured words (like "rayon," "penicillin"); some are even commercial brand names (like "scotchtape," "kleenex," "band-aid") that have come to mean a kind of product, rather than simply the brand of that product made by a particular manufacturer. Other manufacturers of the same product may not like this. What effect do you think it might have on sales?

Identify slang words and terms current among your friends. These change rapidly, often in a single year. Few of them survive. Ask your parents about slang terms that were current when they were young. Have any of these survived? Do your parents still use any of them? Do you? Have your parents or teachers taken up the use of any of your slang terms? To a large extent slang belongs to the language of young people.

When the same language is spoken in widely separated countries, it may evolve differently, using different words for the same new development when it arises. In England and the United States this has happened. What words are used in England that correspond to our "radio," "truck," "gasoline," "hood" (of a car), "trailer," "elevator?" Can you find others that differ?

See if you can find a list of words having to do with horses and horse-drawn vehicles, which formerly were in general use, but now are limited to hobby groups and others who still use horses. How might you go about investigating this?

Evolution of Clothing:

The evolution of clothing has shown long-time trends related to availability of materials and the activities in which people engage. Thus, the introduction of cotton into the Mediterranean world in ancient times, and the availability of silk following the development of trade with the Far East at the close of medieval times, made possible changes in certain types of clothing. The development of various kinds of synthetic fabrics in our own time has produced even wider effects.

The replacement of natural dyes by synthetic ones, which followed the discovery of the first analine dye by the English chemist Perkin in 1858, has resulted in the use of a far greater variety of colors and shades, and the availability of brighter and more permanent colors. How is this comparable to what is happening now in the case of synthetic fabrics? Can you think of other similar examples?

One field of cultural evolution reacts upon another. There are complex interrelationships among different aspects of people's adjustments to the problems of their environment. In ancient times in the Mediterranean lands, workers went naked or nearly so, while women and the non-working classes of men wore long, flowing costumes. With the spread of Christianity and acceptance of its concepts of modesty, working people came to wear clothing, more or less close-fitting, because of their active life.

Women and non-workers continued to wear clothing of long, flowing type. What happened in Polynesia with regard to clothing when missionaries introduced Christianity? What about clothing among primitive tribes at the present time? To what extent do men and women all over the civilized world wear the same kinds of clothing now? Why? How does this compare with conditions fifty years ago? Why?

In western countries, during medieval times, men of the working classes came generally to wear long trousers, but the men of the non-working classes, prior to the political revolutions of the late 1700's, wore knee breeches with elaborate coats, collars, stockings and shoes. Following the French and American Revolutions, the long trousers of the working classes were adopted by all men. Why do you think this happened? Study pictures in books on the history of Europe and America, and see if you can determine just when this change occurred. Examine a series showing the pictures of all of the American presidents. How many points of change in appearance can you find?

Women continued to wear long, flowing clothing generally until World War I. What changes took place in women's clothing in the decades following World War I? Why do you think these changes occurred? When did the custom of women wearing slacks develop? Why?

What has happened to the heavy winter underwear that both men and women used to wear? Why? What has happened at the same time in the case of outdoor clothing for winter? Why?

How have bathing costumes for both men and women evolved during the past seventy-five years? Why?

Study clothing evolution during the past hundred years. What specific changes have occurred in women's clothing? In men's? Which has shown the more rapid changes? Why do you think this is so? Long-term evolution should not be confused with fashion change, but the same trend may reappear in succeeding fashion cycles. What influence do you think fashion has? Temporary? Permanent? Do you think that long dresses for women for general daytime wear will ever come back? For an extended period of time? Why, or why not?

You will find family portraits and other pictures of people long ago the best available source for a study of clothing evolution. Beginning about the time of World War I, with the invention of the small, portable camera, the making of "snapshots" became common. What about the word "kodak?" What is its origin? Examine snapshot collections in your own family and those of your friends. These may now include as many as three or four generations. Pictures of people in advertisements in old magazines are a good source if they are available. Talk to your parents, grandparents and other older people. Most museums contain old costumes. Note the colors of these as well as the costumes themselves. How are they different? Is this due entirely to their age?

Follow-Up:

Trace the evolution of other things that man uses: methods of lighting, methods of heating, weapons, methods of transportation, methods of communication, social and political systems, methods of growing crops---anything that you can see where relationship to environment, and survival of that which works have been determining factors in the evolution of these things.

IDEA-CENTERED LABORATORY SCIENCE

(I-CLS)

The Kind of World a Scientist Thinks He Has Found

Unit E. A Scientist Thinks in Terms of Relationships Rather Than Absolutes

TEACHER NOTES

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TEACHER NOTES

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LABORATORY EXPERIENCE E.1.a.

A Simple Balance

TEACHER NOTES

It is necessary to stress that measuring is really comparing, and that all units of measurement are really arbitrary standards of comparison. Comparing is simply a way of showing relationships. It is necessary, however, to use standard units of measurement for comparison, because only in this way can we be sure that everyone is talking about the same thing. And it is only in this way that we can make quantification meaningful and put it in terms that everyone understands.

You and the students will find it interesting to see how precisely you can measure with your yardstick balance. There may well be "bugs" in your balance that you can neither eliminate nor explain. This, however, will furnish an opportunity to get across to the students the subsidiary concept of margin of error, which in itself will be a valuable experience.

LABORATORY EXPERIENCE E.1.b.

Depth and Pressure

TEACHER NOTES

The measurement of the liquid in the glass tube will show the relationship between depth and pressure. The emphasis is on the Idea that measurement expresses the relationships between (1) the measuring stick and the colored liquid, (2) between the colored liquid and the depth of the water in the container, and (3) between the depth of the water and the measuring stick.

LABORATORY EXPERIENCE E.1.c.

Calories and Degrees

TEACHER NOTES

The important thing here is that the student realizes the importance of relationships. Data of any kind, even measurements, do not stand alone and are of little importance unless they are viewed in relation to other things---- in a broad sense, to their environment.

LABORATORY EXPERIENCE E.1.d.

Speed---A Relationship

TEACHER NOTES

The idea of speed is a common one, but the idea that speed is the expression of the relationship of time and distance is probably new.

Since many students may someday be driving a foreign car using metric distances, the comparison of that speedometer with one on an American car will help them to understand the importance of distance in the relationship with time.

Velocity involves a third factor in the relationship---the idea of direction.

Acceleration is a change of speed. Because the acceleration of gravity is 32 feet per second per second, a penny dropped from a high building can attain the speed of a bullet.

If a tape timer is available, find the acceleration of gravity.

LABORATORY EXPERIENCE E.2.a.

Replicating Simple Patterns

TEACHER NOTES

It is a very valuable experience for the students in connection with this laboratory if they can watch a key being duplicated. If this is not possible, the process should be explained carefully, and if possible, illustrated.

As many examples as possible of the replication of patterns in nature should be cited. The words replication and template (in the sense of pattern) should be fixed in the students' vocabulary.

Have the students try to think of other examples where patterns are used in modern life.

LABORATORY EXPERIENCE E.2.b.

Patterns in Communication

TEACHER NOTES

Discuss general phenomena of wave motion, bringing in as many examples as you can. Talk about how sound waves and light waves are like waves on the surface of water, and how they are different. Talk about earthquake waves and tell how they are related to other types of wave motion.

Talk about the electromagnetic spectrum as a whole, how it is related to visible light and to other types of waves that students have heard about: infra-red (heat), ultraviolet, radio waves, X-rays, cosmic rays. Talk about how they all fit into the total picture of wave motion. Talk about the uses to which various parts of the electromagnetic spectrum are put. Encourage questions. Answer them if you can, but do not hesitate to say, "I don't know."

Any important concept in connection with this laboratory experience is the transference of pattern which takes place in communication: from sound waves to variations in the flow of an electric current, to radio waves, and then, reversing the action, ultimately back to sound waves again. In a simple fashion, this kind of transfer takes place in a can-and-string telephone. Something related to this occurs in the case of motion pictures, and even in ordinary photography and written or printed communication. See how much of this idea you can get across to your students.

LABORATORY EXPERIENCE E.2.c.

We Are What We Are Because ---

TEACHER NOTES

Don't pry into a student's ego by asking him for his answers to the questions. We are what we are because of many interacting factors. Many of our civil rights problems result from a lack of understanding of who a person is, and of all of the interacting factors that make him what he is. Our objective here is to have each student try to understand more fully how many complex and interdependent factors make him the kind of person he is.

LABORATORY EXPERIENCE E.3.a.

What Do We Mean By "Where?"

TEACHER NOTES

The idea back of this laboratory experience is, of course, the same as that which underlies Einstein's Theory of Relativity: "A thing is describable as it is in terms of where it is and when it is in relation to other things, rather than in terms of what it is."

Of course it would be possible to introduce the time variable into our model as well as the position variable which we have used. This would make the model much more complex, and unnecessarily so. The Idea of Frames of Reference can be understood in terms of position and motions.

LABORATORY EXPERIENCE E.3.b.

Illusions

TEACHER NOTES

Discuss with the students situations where sensory illusions may cause real difficulty. Do they ever play a part in misunderstandings between people? In accidents? In making estimates of various kinds? Can people see the same things in different frames of reference? Hear the same things? Think about the same things? How important are frames of reference? Why is it difficult to define a word like democracy?

LABORATORY EXPERIENCE E.3.c.

How Do We Know Where We Are On The Earth?

TEACHER NOTES

Even though students will have studied about latitude and longitude in the elementary school, they will not have acquired an understanding of these as anything other than lines on a map. In this laboratory experience they should develop an understanding of these coordinates as frames of reference.

LABORATORY EXPERIENCE E.4.a.

A Pond Infusion Culture

TEACHER NOTES

Although the directions are written for the individual student, you may wish to set up infusion culture jars and then have the entire class study them together. If you do it this way you should start at least four jars. Individual jars do not always go through a normal succession. Sometimes it is possible to discover a reason for this failure; sometimes not. If each student in class sets up a culture or, if several teams of students do it, and if directions are followed carefully, you have enough alternatives to assure success with some of them.

It is enough to have the students put the living organisms that they see into large categories, as suggested in the directions. If they wish to come to recognize certain genera or other taxonomic groups, such as Paramecium and Copepods. This is an interesting and useful expansion, but in the final summarization of their data, the larger categories are all that is necessary.

You will probably want to verify some of their identifications and therefore you will find the reference books useful. You may also wish to draw rough sketches of the more common organisms on the chalkboard, emphasizing such readily observable characteristics as body shape, size, and outstanding features of appearance. Sketches of this type will enable others to recognize the organisms if they see them. It is well if such sketches can remain on the board during the early progress of the laboratory experience, and be supplemented by additional ones as new organisms are discovered by members of the class. Usually all of the common organisms are seen and identified during the first few periods of observation. Remember that all organisms which appear at any time during the development of the culture must be derived from those that were present in it at the beginning. Nothing new is introduced, but changes in relative numbers make it appear that some organisms are new.

You may wish to work out with the class a means of quantifying the data which have been obtained. This may be done by combining the results of the entire class at the end of each period of observation. Exact counts are not necessary. It is usually sufficient [illegible] state results in terms of rough categories such as "very abundant," "abundant," "many," "few," and "rare." Quantification at this level serves as a useful summary, and where it is carried on for successive periods, it helps to present to the class a picture of the changing scene of the culture as the succession progresses. The sketches on the board are helpful in talking to the class about what they have seen.

LABORATORY EXPERIENCE E.4.b.

A Field Trip in the Laboratory

TEACHER NOTES

The class may be divided into committees of convenient size, each of which can construct a model for a particular kind of plant-animal community. Only types of communities that are known to at least some members of the committee should be used.

Many different kinds of communities may be used. Some might be (1) a forest edge, (2) a forest floor, (3) a pond edge, (4) a suburban backyard, (5) an area in a nearby park, (6) an area on the school ground, (7) a balanced aquarium in the classroom. It may be necessary for the members of the committee to visit a community of the type being used, as a basis for making the model.

Other sources of information about communities might be books, movies, and pictures, but these should not be depended on alone.

LABORATORY EXPERIENCE E.4.c.

Relationship of Acidity and Alkalinity to Yeast Activity

TEACHER NOTES

The only difficult part of this experience is step #4. Practice this operation until you can do it smoothly and easily before you attempt to demonstrate it for the class. They will also need some practice. It is possible that you may have to do it for them.

Since this experience involves the use of gradients, it might be well to review the Idea of Gradients (See Idea Bridge and Laboratory Experiences under D.2.)

LABORATORY EXPERIENCE E.4.d.

Evaporating Power of the Air

TEACHER NOTES

Relative humidity is the relationship between the actual amount of water vapor the air contains at a particular time and the amount that it could contain if it were saturated. The amount that it can contain at a particular time is related to the temperature of the air at that time. As the temperature of the air increases, it expands---Its volume increases. As the air surrounding a source of evaporation, such as a wet bulb thermometer, becomes saturated, air movement may take the saturated air away. Then additional air can come in contact with the source of evaporation and become saturated. Therefore air movement (wind) is a factor in the evaporating power of the air.

LABORATORY EXPERIENCE E.4.e.

Forest Edge Communities

TEACHER NOTES

If it is possible, a class field trip to an attached forest edge community furnishes an excellent beginning for this laboratory experience, because of its orientational value. If this is not possible, a class trip to a park containing brushy wooded areas will give a good start. If no class field trip at all is possible the students may be urged to visit semi-natural forest edge situations "on their own."

If even this type of individual experience is not possible, you may start directly by analyzing urban waste areas.

Remember that detailed identification of species of animals and plants is not necessary nor even desirable at the level at which your students are working. Recognition of different kinds of organisms is possible without identification, and common or assigned names are enough. Relationships are what is important in this laboratory experience. These should receive careful attention and should be stressed.

LABORATORY EXPERIENCE E.4.f.

Interrelationships on Your School Ground

TEACHER NOTES

In this laboratory experience a careful study of conditions that are near and are familiar, is used as a basis for an understanding the broad relationships of climatic factors. The physical environment can be studied in this way with little equipment and without technical background.

You can go as far as you like, or as far as your students' interests will extend, in relating the physical environmental factors as studied on the school ground to local, regional and continental weather and climate.

A distinction between microclimate and macroclimate should be clearly made, and the importance of the physical environmental conditions where an animal or plant actually lives should be stressed.

LABORATORY EXPERIENCE E.4.g.

City Birds

TEACHER NOTES

Most people, including young people of junior high school or middle school age, are scarcely conscious of the existence of city center bird life. They may hear and see these birds but they are not interested in them, unless to consider them a nuisance. Old men may feed pigeons in parks, while house sparrows pick up the leavings. Starlings may become noisy on the upper portions of buildings, and all of them may leave unsightly droppings.

These birds, however, and several native American species, such as the robin and the night hawk, have adapated to man-made habitats, and increased their numbers as they have done so. Pigeons of course, are escapes from domestication. House sparrows and starlings have lived with man and become man-tolerant during thousands of years in the Old World. All of these birds, native and European, are interesting from the standpoint of survival and evolution.

Students usually become interested in these birds, and can learn much by observing them. Through studying these birds, students will learn something about the inner city habitat where they themselves live. This may lead them to work toward improvement of it as a place to live.

LABORATORY EXPERIENCE E.5.a.

Plants and Soil Nutrients

TEACHER NOTES

You can vary this laboratory experience by using different kinds of fertilizer, or different amounts, or both. It should lead to some understanding of the necessary interrelationship of heredity and environment on the part of the students. Nevertheless, you should keep this interrelationship before them as the experiment progresses. You should point out that in no place can you find a characteristic that is "caused by" heredity, or "caused by" environment, working alone. They always work together.

LABORATORY EXPERIENCE E.5.b.

Plants and Light

TEACHER NOTES

In this laboratory experience again, the idea to be taught is the necessary interrelationship of heredity and environment. Neither can produce a trait alone. Any trait is necessarily the result of their working together. Sometimes one is more important than the other. In the case of the albino corn, no amount of environmental influence can overcome the effects of the albino gene. Of course it might be possible in a plant physiology laboratory to feed the plant glucose solution and enable it to live and possibly grow, but still without green pigment.

The *Coleus* plants furnish an interesting, open-ended experience. Environmental factors do influence the development of color, and it is interesting to explore what the relationships are.

LABORATORY EXPERIENCE E.5.c.

Human Characteristics: Heredity or Environment

TEACHER NOTES

The main function of this laboratory experience is to put students in a series of situations where they will have to think about the relationship of heredity and environment in humans.

The eye color experience mainly calls the students' attention to shades of eye color other than brown and blue. The action of diluting, intensifying, and patterning genes is the probable reason for the different shades of brown and blue, and the "in-between" colors. Students should be encouraged, however, to consider the possible modifying role of environment in eye color determination.

The little card puzzle has been used in other laboratory experiences. If the results are remembered by the class it might be possible at this point simply to refer back to it. It might also be interesting, however, to go through it again with the puzzle cut up differently. To see if the same person wins, and if the others hold the same general rank as before. In any case you should prepare the puzzles and the numbered tags ahead of time.

A simple puzzle should be prepared for each member of the class. All puzzles should be made according to the same pattern. Each one consists of a 3" x 5" filing card cut into 10 pieces.

The ten pieces into which the card is cut should be approximately the same size, and of as many shapes as possible. The cuts, however, must all be along straight lines. It is best to draw lines (lightly with a pencil) to indicate the cuts before doing the cutting. The pieces of each puzzle should be placed in envelopes and given to the students, but neither pieces nor envelopes should be marked in any way.

A series of numbered tags, beginning with (1), should be prepared, equal to the number of students in the class. These should be shaken up, and each member of the class should draw a number. This will determine his participation in the series of contests.

LABORATORY EXPERIENCE E.6.a.

Development of a Chick Embryo

TEACHER NOTES

You will need to work closely with the students in this experience. You will need to help them with necessary vocabulary. You will need certainly to help them with manipulation. There is nothing really difficult about studying a chick embryo. What is going on can readily be observed and understood. Unfortunately a minimal amount of new terminology is necessary, and you will certainly need to open the first embryos yourself. Once they have seen it done, there is no reason why the students cannot carry on the operation.

You will probably also have to help them with the references in biology and embryology texts. They can understand the pictures, once they have located them in the books. You will probably have to explain the processes, such as heart formation and organ formation. You may use modeling clay to illustrate inpocketing, outpocketing, folding, thickening, and even cell migration.

All of this effort on your part will be well rewarded when you see the students enjoying the thrilling experience of observing the beating heart of the freshly exposed chick embryo.

LABORATORY EXPERIENCE E.6.b.

Development of a Bean Plant

TEACHER NOTES

Differential growth rates furnish a way of looking at all growth, animal and plant, in terms of a kind of "common denominator." Parts of living organisms grow faster and/or for a longer time than other parts. The forms attained as a result of differential growth rates are therefore a matter of relationships. This idea of differential growth rates is new to the students and should be pointed out to them at every opportunity.

LABORATORY EXPERIENCE E.6.c.

Differential Growth Rates in Humans

TEACHER NOTES

Nearly all of the differences that we use in recognizing individuals of our acquaintance are traceable to differential growth rates. An interesting discussion can result from an attempt to trace selected individual characteristics to differential rates and processes.

Here again, the importance of the idea of differential rates and processes, and the relationships which are involved between rate and time should be stressed.

LABORATORY EXPERIENCE E.6.d.

Developing Stream Patterns

TEACHER NOTES

Work with a stream table can be very messy, but the differences in rate of flow of a stream, in amount of erosion and deposition, and in the formation of stream patterns can be most interestingly shown in this way. Keep in mind that differential rates constitute the mechanism by which stream patterns are formed.

A field trip to observe a river preferably a small one, is an excellent idea if it can be managed. A field trip to observe erosion patterns on dirt piles such as can be found around a site of fresh construction will be very helpful.

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LABORATORY EXPERIENCE E.7.a.

Extending Man's Body With Tools

TEACHER NOTES

The relationship between man and his tools is that a tool is a way of extending man's senses and his capabilities. This is the important understanding to get across in this laboratory experience. There are hundreds of examples in addition to these cited in the laboratory experience. You and the students can easily think of some of these if you keep the idea before you.

LABORATORY EXPERIENCE E.7.b.

Doing Work

TEACHER NOTES

In order for work to be done, energy must be used. A machine does not make it possible for you to do less work. It only makes the work appear to be done more easily. The only way the amount of work one does can be actually decreased is to add another source of energy.

What other sources of energy can be used? Can the energy of the sun be used directly? Indirectly? How? What about the energy of fuels such as oil and coal? Is this energy related to the sun as a source? Are there other sources of energy that can be harnessed to do work? Are these in any way related to the sun as a source?

It would be well to discuss these questions with the class.

LABORATORY EXPERIENCE E.7.c.

Extensions of Man's Body: Simple Machines

TEACHER NOTES

Do not allow yourself or the students to "get lost" in the interesting mechanical relationships involved with levers, inclined planes, wheels and axles and pulleys. Students should learn about these, but they, in themselves, are not the goal of this laboratory experience. The goal is to see simple machines as *extensions of man's body and its capabilities*. This idea should be kept before the students at all times.

LABORATORY EXPERIENCE E.7.d.

Complex Machines and Utilization of Outside Energy

TEACHER NOTES

This laboratory experience serves to show the increasing complexity of man's machines, particularly in connection with the use of outside sources of energy. It is necessary to avoid becoming so interested in the gadgety aspects of this experience that the idea that complex machines and outside sources of energy can be thought of as extensions of man's body is lost sight of. Both teacher and students may "get lost in the trees and miss the forest." Don't allow your students and/or yourself to do this.

LABORATORY EXPERIENCE E.7.e.

Extensions of Man's Body: How They Have Evolved

TEACHER NOTES

This study may be carried on in the form of individual out-of-class projects, or by field trips which may be arranged to suitable places. Probably, in most cases, a combination of these two approaches will prove best. It may be desirable for different students or groups to work on different aspects of the study, and then bring their results together for the benefit of the class.

There should be an excellent basis for profitable class discussions in connection with this laboratory experience. Many everyday experiences of yourself and the students can be related to it.

In any kind of evolution there is the phenomenon of old, primitive, or ancestral types persisting in out-of-the-way places which are marginal or isolated. In these places the environmental conditions have not changed, competition is not great, and the stream of development has passed them by. Students of biological evolution call these primitive types archaic, and the places in which they survive relict areas. Such biological locations are found in deep lakes of ancient origin, mountainous areas, the depths of tropical swamp forests, desert areas, islands in the sea, the extreme edges of continents, and isolated peninsulas off larger land masses. The archaic species of plants and animals found in such places are the "living fossils" of popular journalism. What are some examples?

In the area of cultural evolution, such "living fossils" can be discovered in any of the classes of tools that man uses. They are found in any conservative situation where, for one reason or another, the "stream of living" has passed them by. The necessity for change to meet new situations and problems has not been sufficient to cause them to be abandoned. They are more likely to survive in rural areas than in cities, in hilly or mountainous areas than in plains areas, and in poor soil areas than in good soil areas.

"Language islands" and conservative religious groups preserve antiquated forms of dress, language and other cultural devices. Ceremonies and traditional festivals, such as are carried on in some American communities of European origin and in some Indian tribes, fall into the category of relict areas which preserve antiquated forms, especially of dress. Can you think of any others? What about weddings? Can you think of any cases where these antiquated customs have been artificially perpetuated or revived as tourist attractions?

Kerosene lamps and horse-and-buggy transportation have been retained longest in hilly, mountainous, poor-soil areas. Older people are the ones most likely to cling to "old-fashioned" things, and forms of speech and dress. Why? Horse-drawn farm implements have survived similarly. Old models of automobiles (in everyday use) disappear last in poor, rural, hill districts.

If a museau is available, look in it for old methods of lighting, old forms of transportation, old farm implements, old types of dishes, glassware, furniture, hand tools, and other old things. The Henry Ford Museum and

Greenfield Village at Dearborn, Michigan (a Detroit suburb), has an excellent collection of these things. The Museum of Science and Industry in Chicago has some of them. Almost any historical museum will have at least a few of them.

Antique shops are filled with some kinds of old things. Many people have private collections of some of them. Try to find and study some of these things. Can you identify any trends in their evolution? What kinds of forces and influences do you think shaped their development?

The isolated, mountainous, poor-soil districts of the South preserve many of the language forms of Middle English. This is the English language of the time of Queen Elizabeth I, the King James version of the Bible, and William Shakespeare. Many of the medieval ballads which have long since disappeared in England have been found in America in the southern mountains, which began to be settled when Middle English was still being spoken, and the ballads were still being sung in the home country. Listen to some of these songs in a record collection. If you know any people who come from these areas, listen for differences in their speech. What are some of the differences?

Ancient language forms also persist in the rituals of churches. Since religions tend to be conservative, these are comparable to the survival of other archaic forms. Such church languages are called ecclesiastical languages. The use of Latin as an ecclesiastical language in the Roman Catholic church until recently is well known. Nearly all religions show some phenomena of this kind. What other specific examples can you discover?

Religions may also preserve old clothing types. The clothing worn by Roman Catholic monks and nuns falls in this category. The clothing worn by Roman Catholic religious orders is now being modernized, however, along with the introduction of English in the church services. What other examples can you think of? Generally both archaic language forms and clothing forms tend to preserve the types that were in use at the time the religion was founded, or the particular custom originated. What about Salvation Army uniforms? To what military uniforms are they related? Why?

How is the evolution of man's machines, language, clothing, other cultural forms and ideas--tools in the broad sense for dealing with problems posed by his environment--comparable to the evolution of plants and animals during the earth's long history? In what ways is it similar? In what ways different?